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HYD-249

MASTER

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL EXPERIMENTS FOR THE DESIGN OF THE HORSE MESA DAM SPILLWAYS--SALT RIVER PROJECT, ARIZONA

Hydraulic Laboratory Report No. Hyd.-249

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

NOVEMBER 30, 1948

FOREWARD

Hydraulic model studies for the design of the Horse Mesa Dam spillways were made by H. W. Brewer and H. G. Dewey during the late part of 1935 and the early part of 1936. Because of the pressure of work, the final report was not published until 1948.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Research and Geology Division
Denver, Colorado

Date: November 30, 1948

Laboratory Report No. 249
Hydraulic Laboratory
Tests by: H. G. Dewey, Jr.
H. W. Brewer
Compiled by: J. E. Warnock
H. M. Martin

Subject: Hydraulic model experiments for the design of the Horse Mesa Dam spillways--Salt River Project, Arizona..

SUMMARY

A model of Horse Mesa Dam was tested to obtain an economical method of increasing the capacity of the existing spillway. It was also desirable that some means be devised to decrease the spray from the spillways, which is detrimental to the electrical installation on the powerhouse and canyon walls, as the water carries an appreciable amount of salts in solution.

Horse Mesa spillway capacity was increased to 147,000 second-feet with a reservoir elevation of 1920.0 by the addition of a tunnel spillway, which proved the most economical method. The flow conditions in the tunnel were satisfactory for all discharges and no negative pressures were observed.

As the spray cannot be simulated in a model, it was difficult to determine a method of reducing the spray from the spillways. Buckets at the downstream end of the spillways indicated that the spray might be less than in the original design. The models were used for comparison and it was assumed that the plan producing the best results in the model would also produce the best results in the prototype.

These investigations were conducted by the personnel of the Hydraulic Laboratory of the Bureau of Reclamation. Descriptions of tests and the results obtained are reported herein as the final report.

INTRODUCTION

Horse Mesa Dam is located on the Salt River about 37 miles east of Phoenix, Arizona (Figure 1). It was built by the Salt River Valley Water Users Association and was completed in 1927. The dam is of the concrete arch type, 311 feet in height (Figure 2), with a spillway (crest elevation 1891.0) at either abutment (Figures 3, 4, and 5) having a total capacity of 100,000 second-feet. A spillway tunnel was incorporated in the final design (Figures 6 and 7) adjacent to the northwest or right spillway increasing the total capacity to 147,000 second-feet. The maximum designed reservoir elevation is 1920.0 which is also the elevation of the parapets on the dam.

THE MODEL

A model of the Horse Mesa Dam was built in the Denver Hydraulic Laboratory on a scale of 1:90. The model was constructed in a tank of wooden construction and lined with light galvanized sheet metal (Figure 8). The arch of the dam was constructed of 10-gage, black iron, and the parapet and bridge were of redwood. The powerhouse was built of wood and painted to represent the prototype powerhouse. The spillways consisted of concrete placed between metal. Templates and the wooden bridge over the spillway were supported on redwood piers (Figures 9, 10A and 10B). The sloping topography upstream from the crest was constructed of galvanized sheet metal and the topography below the dam was of concrete and gravel.

Water was supplied to the forebay of the model through a 6-inch pipe from a constant-head tank. As the water from the forebay flowed at right angles to the spillways, curved vanes, of 20-gage galvanized iron, were placed in the forebay to guide the water in the direction it would approach the spillway in the prototype. Floating boards were employed in the forebay to decrease the surface waves present due to the short distance from the inlet to the spillways. The tailwater below the dam was controlled by a hinged gate (Figure 8). The water passed over the spillway, over the tailwater control gate, and then flowed into a return flume which led to the box of a 90-degree V-notch weir. Here the discharge was measured and pumped into the constant-head tank for recirculation.

The reservoir elevation in the model was observed by a hookgage located in a stilling-well as shown on Figure 8. The tailwater elevation was observed from a manometer tube connected to an outlet in the bottom of the tank downstream from the dam. The head on the 90-degree V-notch measuring weir was observed from two hookgages which operated in stilling-wells mounted on the side of the weir tank.

Discharge Capacity of Original Design

The capacity of the spillway with crest at elevation 1891.0 and a reservoir elevation of 1920.0 was 100,000 second-feet. Figure 11 shows the head discharge relation for the spillway as originally built, and Figure 10C shows these spillways discharging 100,000 second-feet. Figure 11 indicates that a reservoir elevation of 1926.2 would have been necessary to discharge 150,000 second-feet. At this elevation, the water would have flowed over the parapets, resulting in destruction of the powerhouse. Figure 10D shows the model discharging 157,000 second-feet with a reservoir elevation of 1926.75. The above observations indicated that, to increase the capacity of the spillways, it would be necessary to lower the crests or to construct an auxiliary spillway.

Echelon Spillways

The model spillways were altered to represent the echelon type (Figure 12). The overflow section of the spillways were constructed of concrete placed between metal templates and redwood piers were installed on the crest on echelon to the flow. The spillway crests were lowered 2 feet (elevation 1889.0), and a bucket downstream from the crest was added in an attempt to decrease the spray (Figure 13).

The combined capacity of the echelon spillways was 148,000 second-feet with reservoir elevation at 1920.0 Figure 14 shows the discharge of each spillway and the combined discharges for various reservoir elevations. Figure 13 shows the spillways discharging 148,000 second-feet. There appeared to be less spray with the added bucket downstream from the spillway crests than in the original model.

As this design was costly due to the necessity of rebuilding the piers and resetting the gates, to allow for lowering the crest, a design requiring the construction of an auxiliary spillway tunnel was investigated.

Semifinal Design

In the plan, the original spillways were altered and an auxiliary spillway tunnel constructed (Figure 15). The piers on the spillway were modified (Figure 16), and a bucket downstream from the crest was added. The model spillway crests and buckets were constructed of concrete placed between metal templates. Piers and bridge structures were of redwood and the training-walls consisted of metal. A spillway tunnel was also incorporated in this design (Figure 17), with crest at elevation 1869.50. Figures 18, 19A, and 19C show the model constructed to this design.

For the semifinal design, the left spillway had a capacity of 36,500 second-feet and the right spillway had a capacity of 65,200 second-feet with the reservoir elevation at 1920.0 (Figure 20) which made the combined capacity 101,700 second-feet. Figure 20 gives the discharge of the right and left spillways for various reservoir elevations. Figures 19B and 19D show the two spillways discharging with maximum pond elevation (1920.0).

The relation of the discharge through the tunnel to the reservoir elevation is shown on Figure 20. The discharge for maximum reservoir elevation was 47,600 second-feet. Figure 22 shows the flow conditions for the maximum reservoir elevation and Figure 21 shows the water surface and pressures in the inclined tunnel for maximum discharge. Negative pressures did not exist and flow in the tunnel was satisfactory for all discharges. A pier nose was evolved (Figure 15), which produced satisfactory entrance conditions to the tunnels.

For geological reasons, it was necessary to relocate the centerline of the tunnel in the field.

Final Design

The necessity for the tunnel relocation was discovered some time after the first model was dismantled and it was therefore requisite to construct another model as the entrance conditions to the two were quite different. In the second model, it was necessary to construct only the right spillway and the tunnel (Figure 23). The centerline of the tunnel was moved 30 feet (prototype) to the right but remained parallel to the former centerline. It was only necessary to study the flow conditions to the tunnel and right spillway as the remainder of the structure was the same as the original.

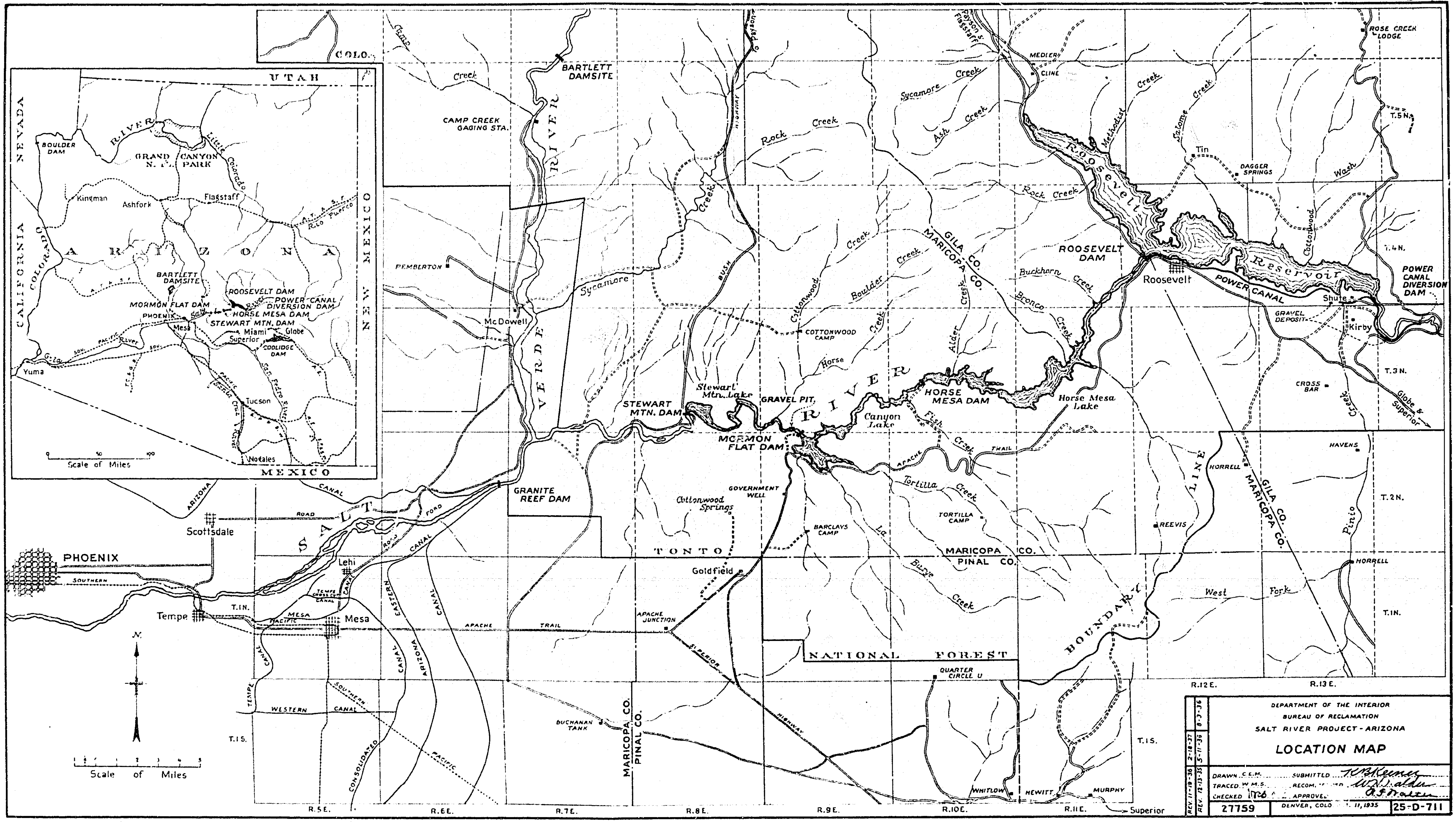
A tank was constructed of wood and lined with light galvanized sheet metal. The downstream end of the tunnel was connected to a separate weir box which was used to calibrate the flow through the spillway tunnel. The right spillway was constructed as in the semifinal design and the arch of the dam consisted of 16-gage black iron. Rock baffles were used to produce uniform velocity upstream from the model and upstream from the small 90-degree V-notch measuring weir.

Discharge capacity and flow conditions. A satisfactory approach was developed (Figures 23 and 24A) and the discharge relation for the various reservoir elevations for this tunnel is shown plotted on Figure 20. Figure 24B shows the entrance conditions with the tunnel discharging 25,000 second-feet, and Figure 24C shows the tunnel and the spillway discharging 47,000 and 65,200 second-feet, respectively, with a reservoir elevation of 1920.0. Figure 25 shows the water surface in the approach to the tunnel for maximum discharge.

The model of the final design indicated a capacity of 150,000 second-feet with all spillways operating for a reservoir elevation of 1920.0.

Spray below powerhouse. Spray cannot be tested in a model due to the inability to obtain a liquid with the proper viscosity and surface tension. The models were therefore compared on the basis that the layout producing the smoothest flow in the model would create the least spray in the prototype. The quantity of spray produced could not be determined in the model and the use of buckets at the downstream end of the spillways only indicated that the spray at the powerhouse may be less than in the original design.

FIGURE 1



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SALT RIVER PROJECT - ARIZONA
LOCATION MAP
DRAWN C.E.M. SUBMITTED
TRACED W.M.S. RECOM.
CHECKED APPROVED
27759
DENVER, COLO. 11, 1935
25-D-711
UTAH
NEVADA
CALIFORNIA
ARIZONA
NEW MEXICO
MEXICO
COLO.
BOULDER DAM
GRAND CANYON N.P. PARK
Kingman
Ashfork
Flagstaff
BARTLETT DAMSITE
ROOSEVELT DAM
POWER CANAL DIVERSION DAM
MORMON FLAT DAM
HORSE MESA DAM
STEWART MTN. DAM
PHOENIX
Mesa
Miami
Globe
Superior
COOLIDGE DAM
Yuma
Tucson
Nogales
Scale of Miles
CAMP CREEK GAGING STA.
PEMBERTON
McDowell
VERDE RIVER
GRANITE REEF DAM
Scottsdale
PHOENIX
SALT
Lehi
Tempe
Mesa
APACHE TRAIL
APACHE JUNCTION
Goldfield
STEWART MTN. DAM
Stewart Mtn. Lake
GRAVEL PIT
MORMON FLAT DAM
Canyon Lake
HORSE MESA DAM
Horse Mesa Lake
Roosevelt
ROOSEVELT DAM
Roosevelt Reservoir
POWER CANAL
POWER CANAL DIVERSION DAM
Shute
GRAVEL DEPOSIT
Kirby
CROSS BAR
Globe & Superior
Tin
DAGGER SPRINGS
ROSE CREEK LODGE
MEDLER
CLINE
COTTONWOOD CAMP
Cottonwood Springs
GOVERNMENT WELL
BARCLAYS CAMP
TORTILLA CAMP
Tortilla Creek
REEVIS
HORRELL
HAVENS
TONTO NATIONAL FOREST
BOUNDARY LINE
GILA CO.
MARICOPA CO.
PINAL CO.
QUARTER CIRCLE U
BUCHANAN TANK
WHITLOW
HEWITT
MURPHY
Superior
WESTERN CANAL
CONSOLIDATED CANAL
EASTERN CANAL
ARIZONA CANAL
SOUTHERN PACIFIC
HIGHWAY
T.5N.
T.4N.
T.3N.
T.2N.
T.1N.
T.1S.
R.5E.
R.6E.
R.7E.
R.8E.
R.9E.
R.10E.
R.11E.
R.12E.
R.13E.
Scale of Miles

FIGURE 2

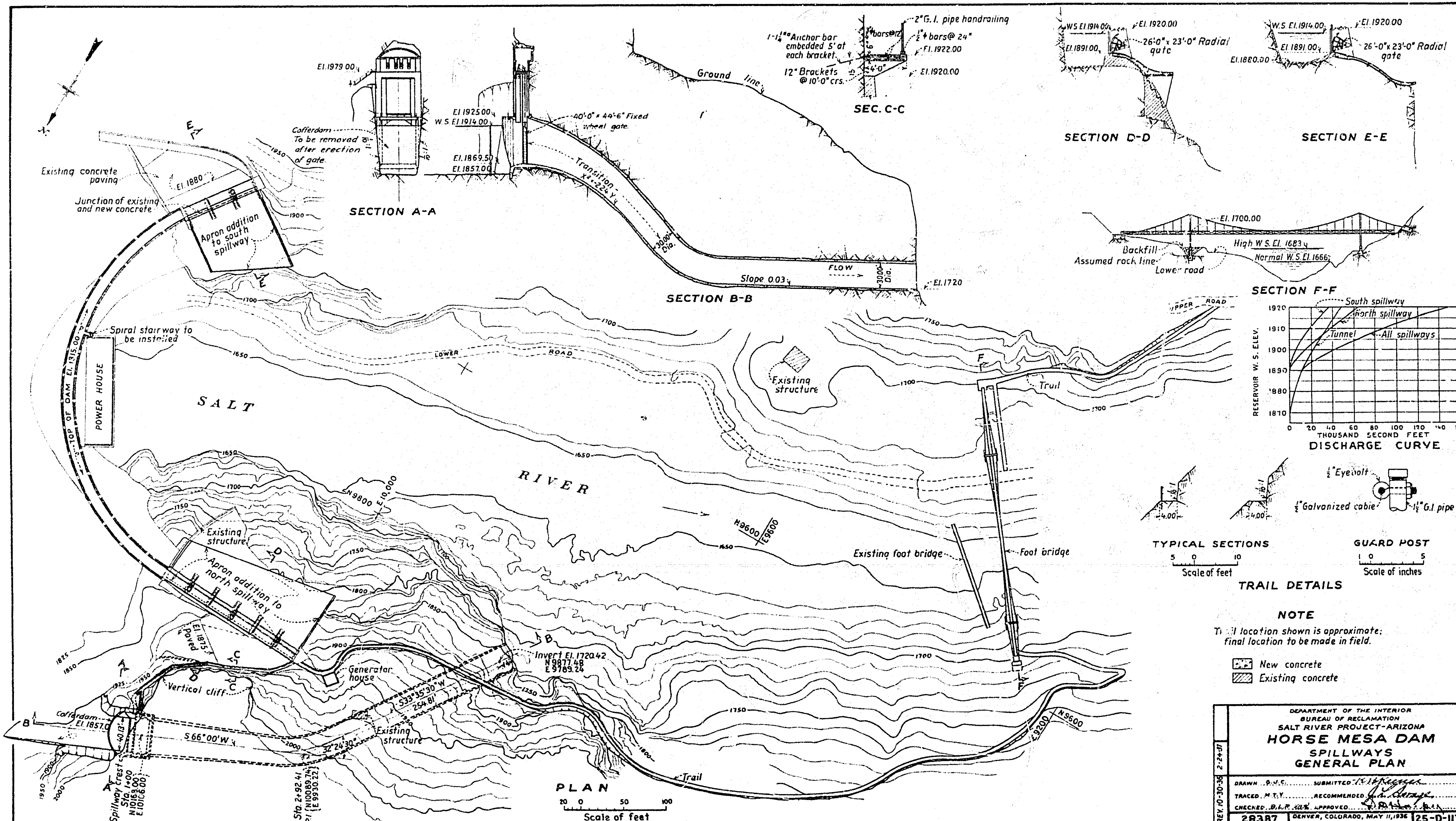

SECTION A-A
SECTION B-B
SEC. C-C
SECTION D-D
SECTION E-E
SECTION F-F
Cofferdam To be removed after erection of gate.
40'-0" x 44'-6" Fixed wheel gate.
Transition
Ground line
FLOW
Slope 0.03
2" G.I. pipe handrailing
12" Brackets @ 10'-0" crs.
26'-0" x 23'-0" Radial gate
Backfill
Assumed rock line
Lower road
High W.S. El. 1683
Normal W.S. El. 1666
DISCHARGE CURVE
South spillway
North spillway
Tunnel
All spillways
RESERVOIR W.S. ELEV.
THOUSAND SECOND FEET
Existing concrete paving
Junction of existing and new concrete
Apron addition to south spillway
Spiral stairway to be installed
POWER HOUSE
TOP OF DAM El. 1915.00
SALT RIVER
LOWER ROAD
UPPER ROAD
Existing structure
Apron addition to north spillway
Generator house
Vertical cliff
Cofferdam
Spillway crest
Invert El. 1720.42 N 9877.48 E 9789.24
S 66°00'W
S 33°35'30"W
Existing foot bridge
Foot bridge
Trail
PLAN
Scale of feet
TYPICAL SECTIONS
GUARD POST
1/2" Eyebolt
1/2" Galvanized cable
1 1/2" G.I. pipe
Scale of inches
TRAIL DETAILS
NOTE
Trail location shown is approximate; final location to be made in field.
New concrete
Existing concrete
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SALT RIVER PROJECT-ARIZONA
HORSE MESA DAM
SPILLWAYS
GENERAL PLAN
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
28387
DENVER, COLORADO, MAY 11, 1936
25-D-1172

FIGURE 3

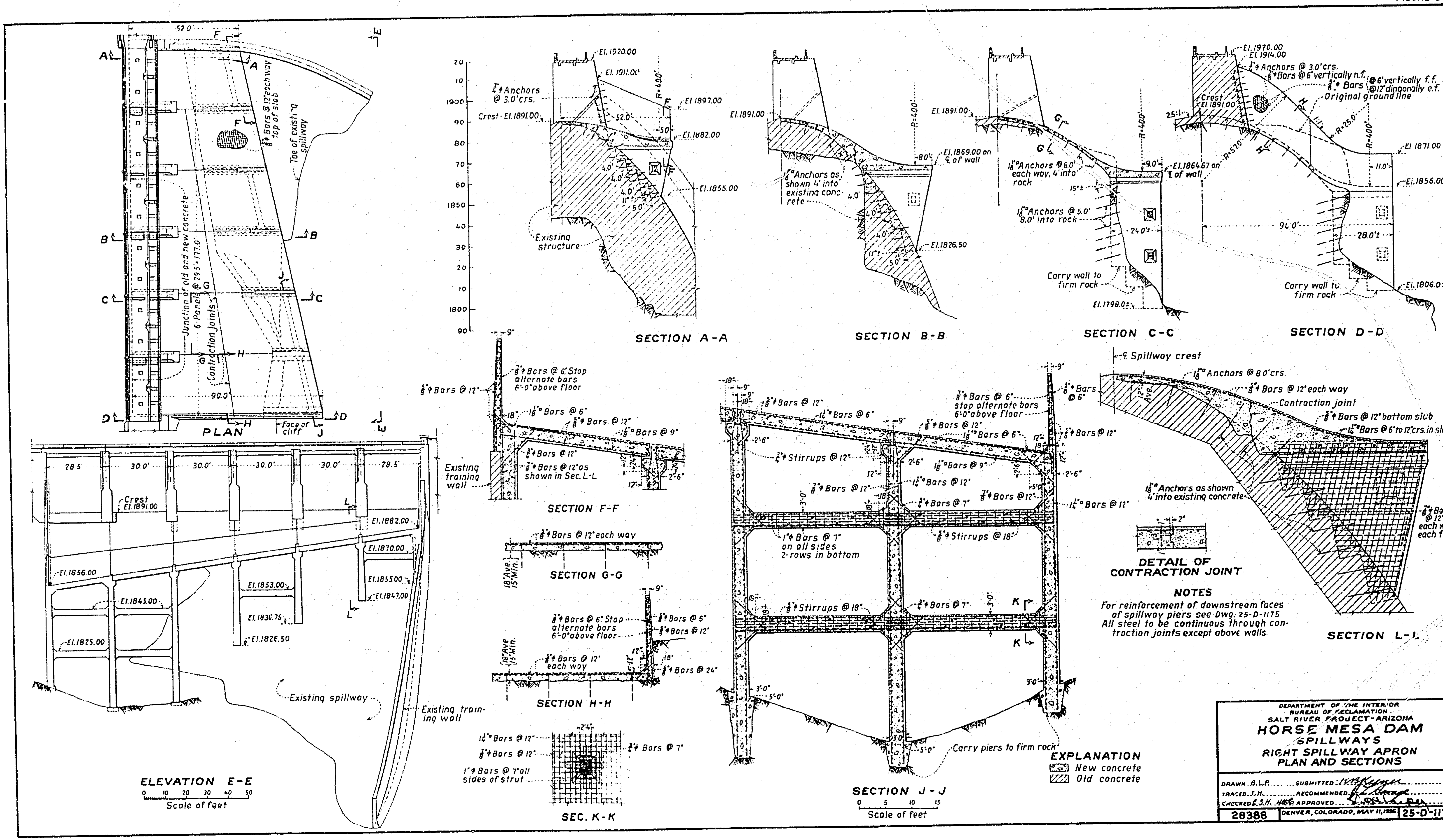
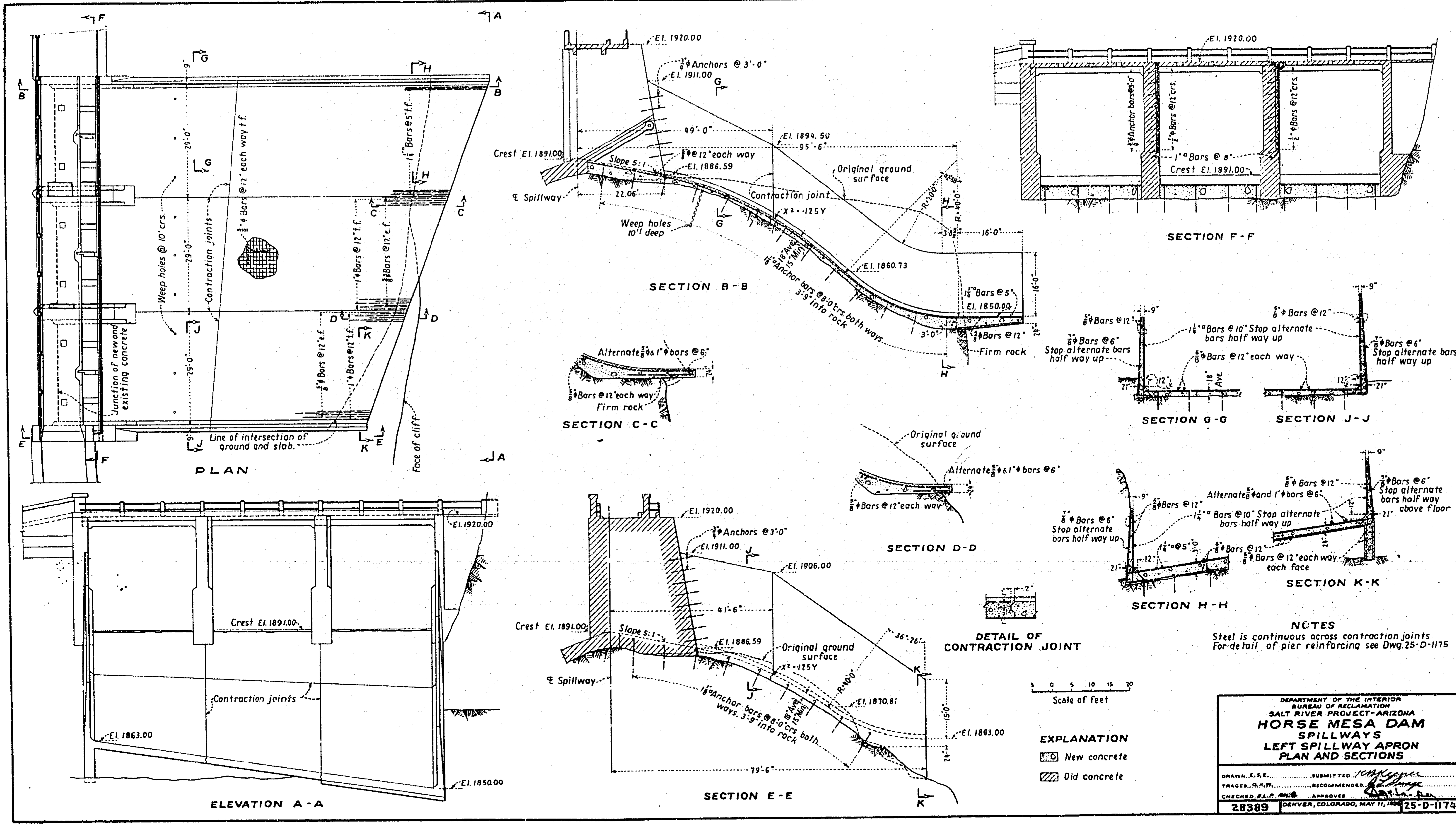

PLAN
Junction of old and new concrete
6-Panels @ 29.5'=177.0'
Contraction joints
Toe of existing spillway
Face of cliff
SECTION A-A
Existing structure
Crest - El. 1891.00
El. 1920.00
El. 1911.00
El. 1897.00
El. 1882.00
El. 1855.00
SECTION B-B
El. 1869.00 on ℄ of wall
El. 1826.50
SECTION C-C
El. 1864.67 on ℄ of wall
Carry wall to firm rock
El. 1798.0±
SECTION D-D
Original ground line
El. 1871.00
El. 1856.00
El. 1806.0±
Carry wall to firm rock
SECTION F-F
Existing training wall
SECTION G-G
SECTION H-H
SEC. K-K
SECTION J-J
Carry piers to firm rock
SECTION L-L
℄ Spillway crest
Contraction joint
DETAIL OF CONTRACTION JOINT
NOTES
For reinforcement of downstream faces of spillway piers see Dwg. 25-D-1175
All steel to be continuous through contraction joints except above walls.
EXPLANATION
New concrete
Old concrete
ELEVATION E-E
Crest El. 1891.00
Existing spillway
Existing training wall
Scale of feet
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SALT RIVER PROJECT-ARIZONA
HORSE MESA DAM
SPILLWAYS
RIGHT SPILLWAY APRON
PLAN AND SECTIONS
DENVER, COLORADO, MAY 11, 1936
28388
25-D-1173

FIGURE 4


PLAN
ELEVATION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
SECTION J-J
SECTION H-H
SECTION K-K
DETAIL OF CONTRACTION JOINT
Crest El. 1891.00
El. 1920.00
El. 1863.00
El. 1850.00
Contraction joints
Weep holes @ 10' crs.
Junction of new and existing concrete
Line of intersection of ground and slab.
Face of cliff
Original ground surface
Firm rock
℄ Spillway
Scale of feet
EXPLANATION
New concrete
Old concrete
NOTES
Steel is continuous across contraction joints
For detail of pier reinforcing see Dwg. 25-D-1175
DEPARTMENT OF THE INTERIOR
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SALT RIVER PROJECT-ARIZONA
HORSE MESA DAM
SPILLWAYS
LEFT SPILLWAY APRON
PLAN AND SECTIONS
28389
DENVER, COLORADO, MAY 11, 1936
25-D-1174

FIGURE 5

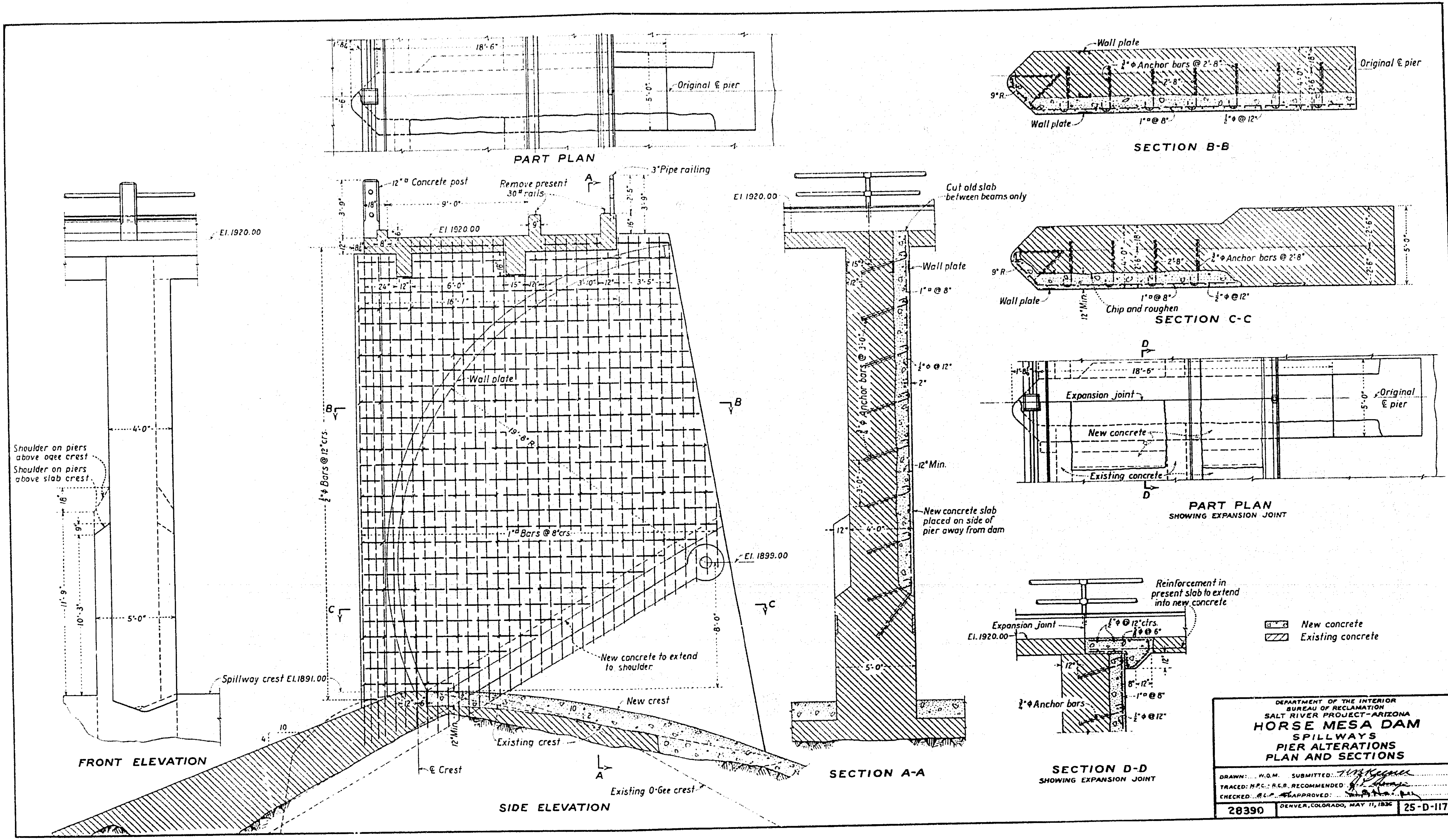
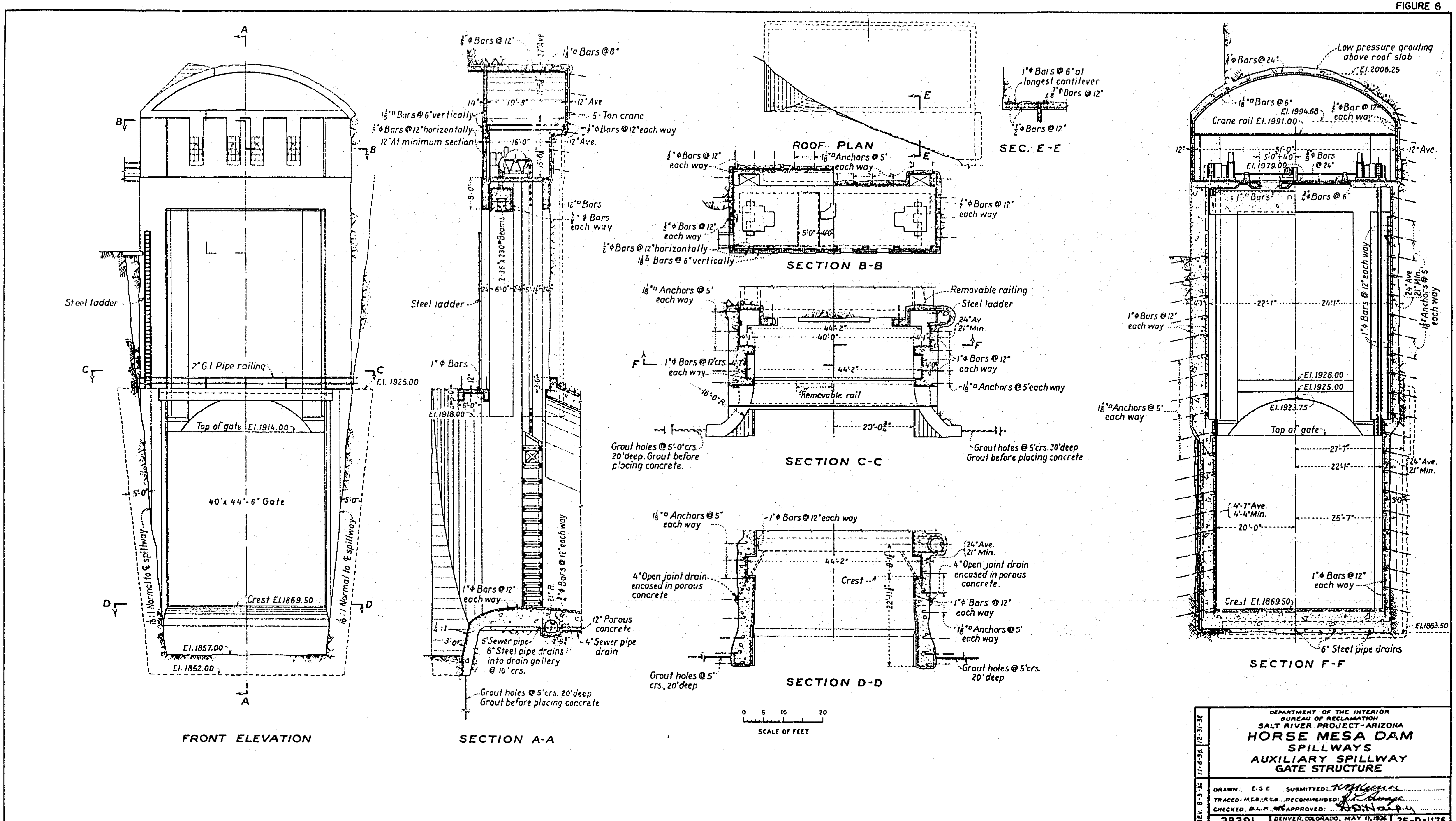

PART PLAN
Original ℄ pier
18'-6"
5'-0"
SECTION B-B
Wall plate
½"φ Anchor bars @ 2'-8"
Original ℄ pier
9"R.
1"φ @ 8"
½"φ @ 12"
SECTION C-C
Chip and roughen
12" Min.
PART PLAN
SHOWING EXPANSION JOINT
Expansion joint
New concrete
Existing concrete
FRONT ELEVATION
El. 1920.00
Shoulder on piers above ogee crest
Shoulder on piers above slab crest
4'-0"
5'-0"
Spillway crest El. 1891.00
SIDE ELEVATION
12"□ Concrete post
Remove present 30# rails
3" Pipe railing
El 1920.00
½"φ Bars @ 12" crs.
1"φ Bars @ 8" crs.
Wall plate
19'-8" R.
El. 1899.00
New concrete to extend to shoulder
New crest
Existing crest
℄ Crest
Existing O-Gee crest
SECTION A-A
Cut old slab between beams only
½"φ Anchor bars @ 3'-0"
12" Min.
New concrete slab placed on side of pier away from dam
SECTION D-D
SHOWING EXPANSION JOINT
Reinforcement in present slab to extend into new concrete
Expansion joint
El. 1920.00
½"φ Anchor bars
New concrete
Existing concrete
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SALT RIVER PROJECT—ARIZONA
HORSE MESA DAM
SPILLWAYS
PIER ALTERATIONS
PLAN AND SECTIONS
DRAWN: W.O.M. SUBMITTED:
TRACED: M.P.C.; R.C.B. RECOMMENDED:
CHECKED: R.L.P. APPROVED:
28390
DENVER, COLORADO, MAY 11, 1936
25-D-1175

FIGURE 6


FRONT ELEVATION
SECTION A-A
ROOF PLAN
SEC. E-E
SECTION B-B
SECTION C-C
SECTION D-D
SECTION F-F
Steel ladder
2" G.I. Pipe railing
El. 1925.00
Top of gate El. 1914.00
40' x 44'-6" Gate
Crest El. 1869.50
El. 1857.00
El. 1852.00
½:1 Normal to ℄ spillway
5-Ton crane
2-36" x 230# Beams
El. 1918.00
12" Porous concrete
6" Sewer pipe
6" Steel pipe drains into drain gallery @ 10' crs.
4" Sewer pipe drain
Grout holes @ 5' crs. 20' deep Grout before placing concrete
1" ϕ Bars @ 6" at longest cantilever
Removable railing
Removable rail
Grout holes @ 5'-0" crs. 20' deep. Grout before placing concrete.
4" Open joint drain encased in porous concrete
Low pressure grouting above roof slab
El. 2006.25
El. 1994.68
Crane rail El. 1991.00
El. 1979.00
El. 1928.00
El. 1923.75
Top of gate
Crest El. 1869.50
El. 1863.50
6" Steel pipe drains
0 5 10 20
SCALE OF FEET
DEPARTMENT OF THE INTERIOR
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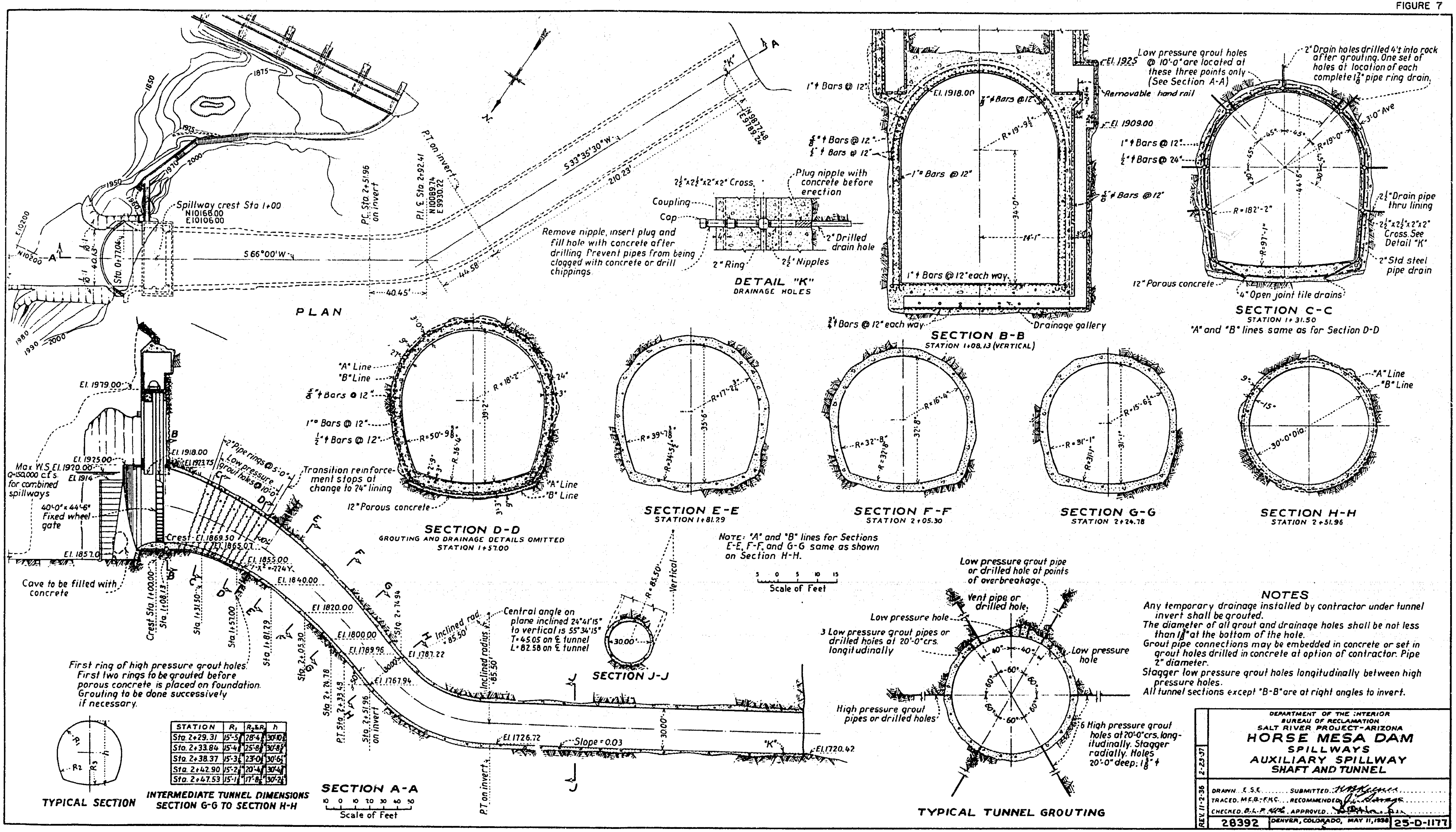
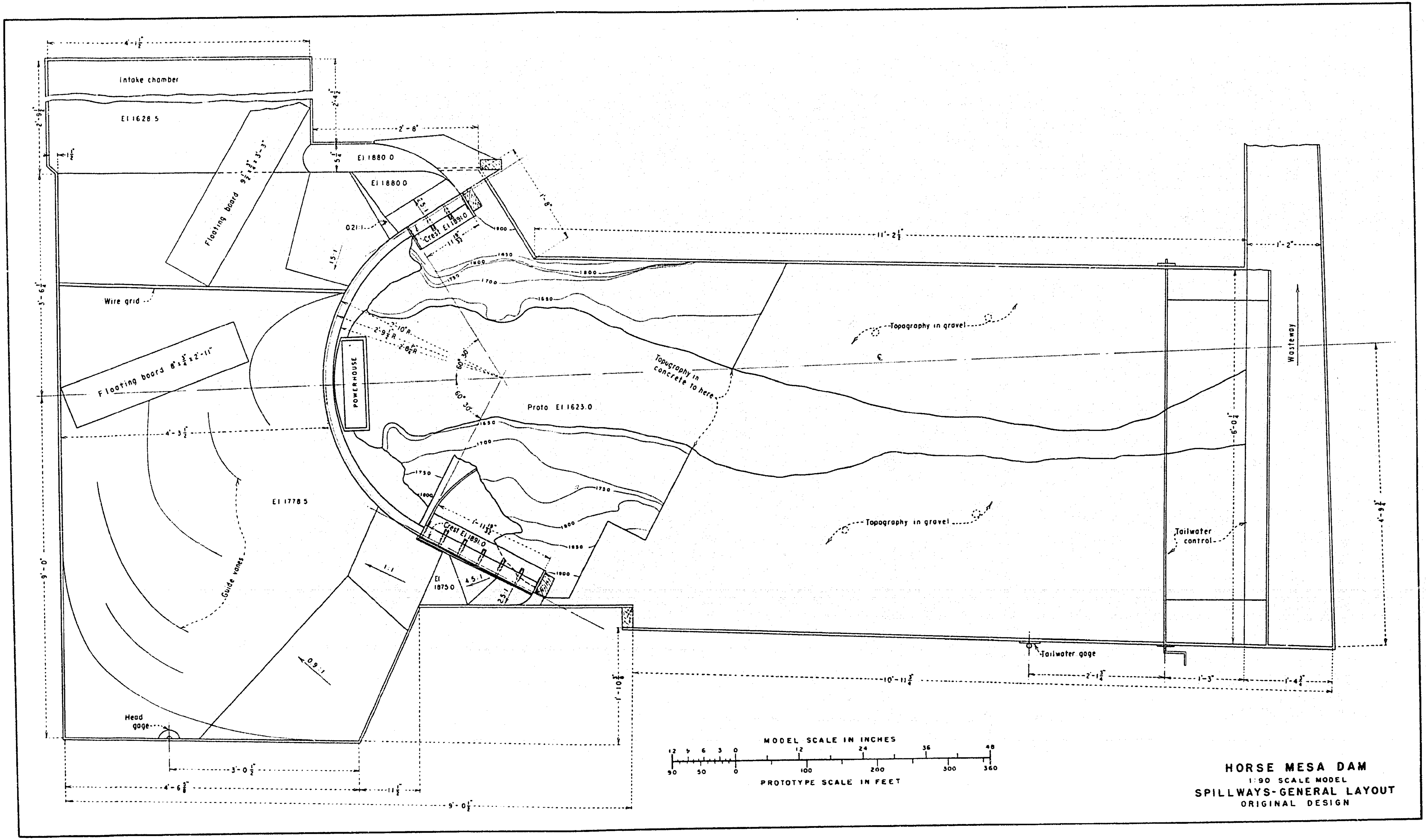
SALT RIVER PROJECT-ARIZONA
HORSE MESA DAM
SPILLWAYS
AUXILIARY SPILLWAY
GATE STRUCTURE
DRAWN: E.S.E. SUBMITTED:
TRACED: M.E.B.; R.S.B. RECOMMENDED:
CHECKED: D.L.P. APPROVED:
28391
DENVER, COLORADO, MAY 11, 1936
25-D-1176

FIGURE 7



PLAN
Spillway crest Sta 1+00
N10168.00
E10106.00
S 66°00'W
S 33°35'30"W
210.23'
40.45'
44.58'
P.C. Sta 2+51.96 on invert
P.I. ℄ Sta 2+92.41
N10089.74
E9930.22
P.T. on invert
N.9877.48
E.9789.24
Remove nipple, insert plug and fill hole with concrete after drilling. Prevent pipes from being clogged with concrete or drill chippings
DETAIL "K"
DRAINAGE HOLES
2½"x2½"x2"x2" Cross
Plug nipple with concrete before erection
Coupling
Cap
2" Drilled drain hole
2" Ring
2½" Nipples
SECTION B-B
STATION 1+08.13 (VERTICAL)
El. 1925
El. 1918.00
El. 1909.00
Removable hand rail
1" ɸ Bars @ 12"
¾" ɸ Bars @ 12"
1" ɸ Bars @ 12" each way
¾" ɸ Bars @ 12" each way
Drainage gallery
SECTION C-C
STATION 1+31.50
"A" and "B" lines same as for Section D-D
Low pressure grout holes @ 10'-0" are located at these three points only (See Section A-A)
2" Drain holes drilled 4'± into rock after grouting. One set of holes at location of each complete 1⅞" pipe ring drain.
12" Porous concrete
4" Open joint tile drains
2½" Drain pipe thru lining
2½"x2½"x2"x2" Cross. See Detail "K"
2" Std steel pipe drain
SECTION D-D
GROUTING AND DRAINAGE DETAILS OMITTED
STATION 1+57.00
"A" Line
"B" Line
12" Porous concrete
SECTION E-E
STATION 1+81.29
SECTION F-F
STATION 2+05.30
SECTION G-G
STATION 2+24.78
SECTION H-H
STATION 2+51.96
30'-0" Dia.
Note: "A" and "B" lines for Sections E-E, F-F, and G-G same as shown on Section H-H.
Scale of Feet
El. 1979.00
Max W.S. El. 1920.00
Q=150,000 c.f.s. for combined spillways
El. 1925.00
El. 1914
40'-0" x 44'-6" Fixed wheel gate
El. 1857.0
Cave to be filled with concrete
Crest-El. 1869.50
El. 1855.00
El. 1840.00
El. 1820.00
El. 1800.00
El. 1789.96
El. 1787.22
El. 1767.94
El. 1726.72
El. 1720.42
Slope = 0.03
2" Pipe rings @ 5'-0"
Low pressure grout holes @ 10'-0"
Transition reinforcement stops at change to 24" lining
Inclined rad. = 85.50'
Inclined radius = 85.50'
Central angle on plane inclined 24°41'15" to vertical is 55°34'15"
T=45.05 on ℄ tunnel
L=82.58 on ℄ tunnel
SECTION J-J
First ring of high pressure grout holes. First two rings to be grouted before porous concrete is placed on foundation. Grouting to be done successively if necessary.
TYPICAL SECTION
STATION	R1	R2&R3	h
Sta. 2+29.31	15'-5"	28'-4"	30'-10"
Sta. 2+33.84	15'-4"	25'-8"	30'-8"
Sta. 2+38.37	15'-3"	23'-0"	30'-6"
Sta. 2+42.90	15'-2"	20'-4"	30'-4"
Sta. 2+47.53	15'-1"	17'-8"	30'-2"
INTERMEDIATE TUNNEL DIMENSIONS SECTION G-G TO SECTION H-H
SECTION A-A
Scale of Feet
TYPICAL TUNNEL GROUTING
Low pressure grout pipe or drilled hole at points of overbreakage
Vent pipe or drilled hole
Low pressure hole
3 Low pressure grout pipes or drilled holes at 20'-0" crs. longitudinally
High pressure grout pipes or drilled holes
6 High pressure grout holes at 20'-0" crs. longitudinally. Stagger radially. Holes 20'-0" deep; 1⅞" ɸ
NOTES
Any temporary drainage installed by contractor under tunnel invert shall be grouted.
The diameter of all grout and drainage holes shall be not less than 1⅞" at the bottom of the hole.
Grout pipe connections may be embedded in concrete or set in grout holes drilled in concrete at option of contractor. Pipe 2" diameter.
Stagger low pressure grout holes longitudinally between high pressure holes.
All tunnel sections except "B-B" are at right angles to invert.
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SALT RIVER PROJECT-ARIZONA
HORSE MESA DAM
SPILLWAYS
AUXILIARY SPILLWAY
SHAFT AND TUNNEL
DRAWN E.S.S.
TRACED M.E.B.-F.K.C.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
28392
DENVER, COLORADO, MAY 11, 1936
25-D-1177

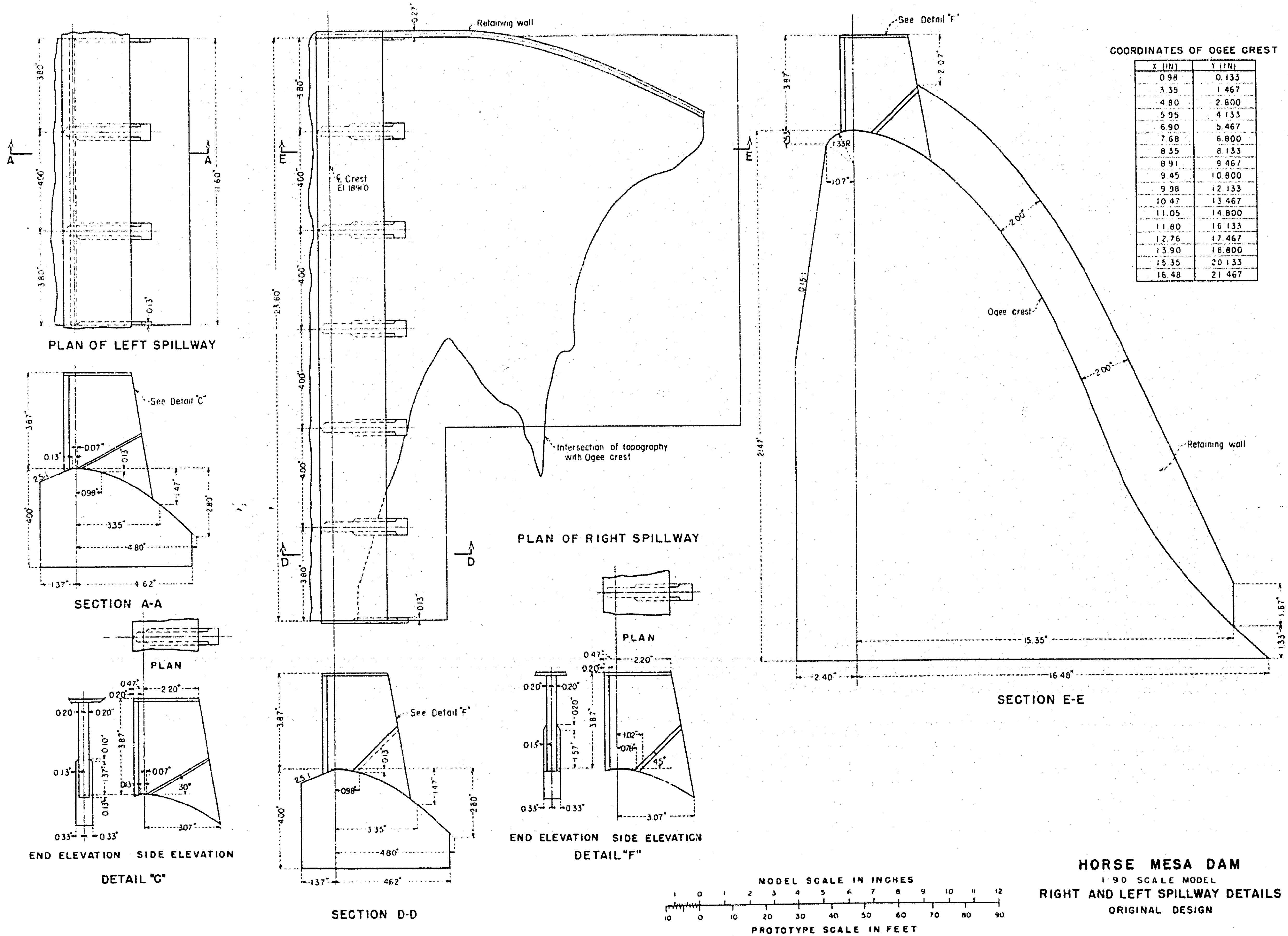


HORSE MESA DAM

1:90 SCALE MODEL

SPILLWAYS-GENERAL LAYOUT

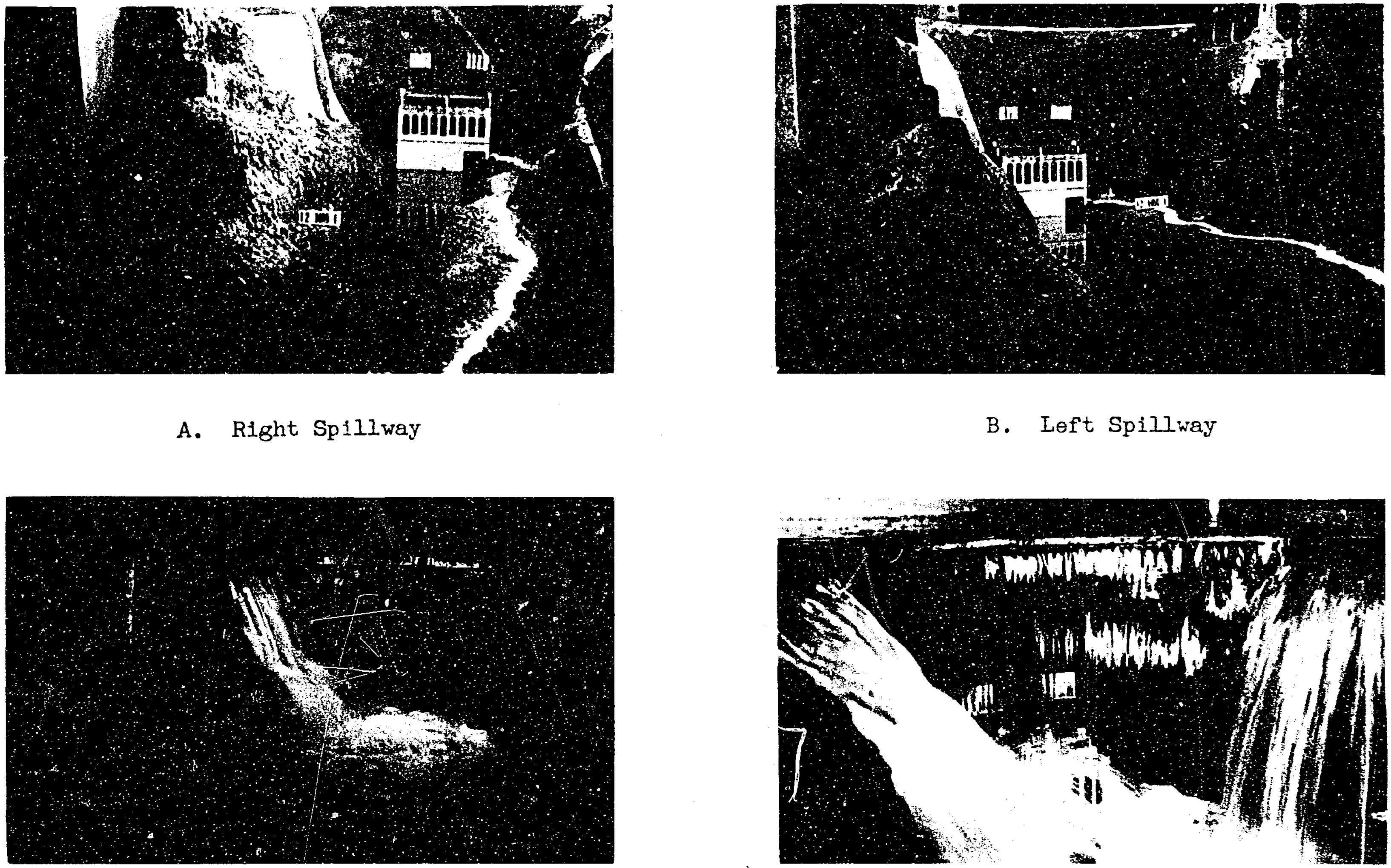
ORIGINAL DESIGN



COORDINATES OF OGEE CREST

X (IN)	Y (IN)
0.98	0.133
3.35	1.467
4.80	2.800
5.95	4.133
6.90	5.467
7.68	6.800
8.35	8.133
8.91	9.467
9.45	10.800
9.98	12.133
10.47	13.467
11.05	14.800
11.80	16.133
12.76	17.467
13.90	18.800
15.35	20.133
16.48	21.467

HORSE MESA DAM
1:90 SCALE MODEL
RIGHT AND LEFT SPILLWAY DETAILS
ORIGINAL DESIGN



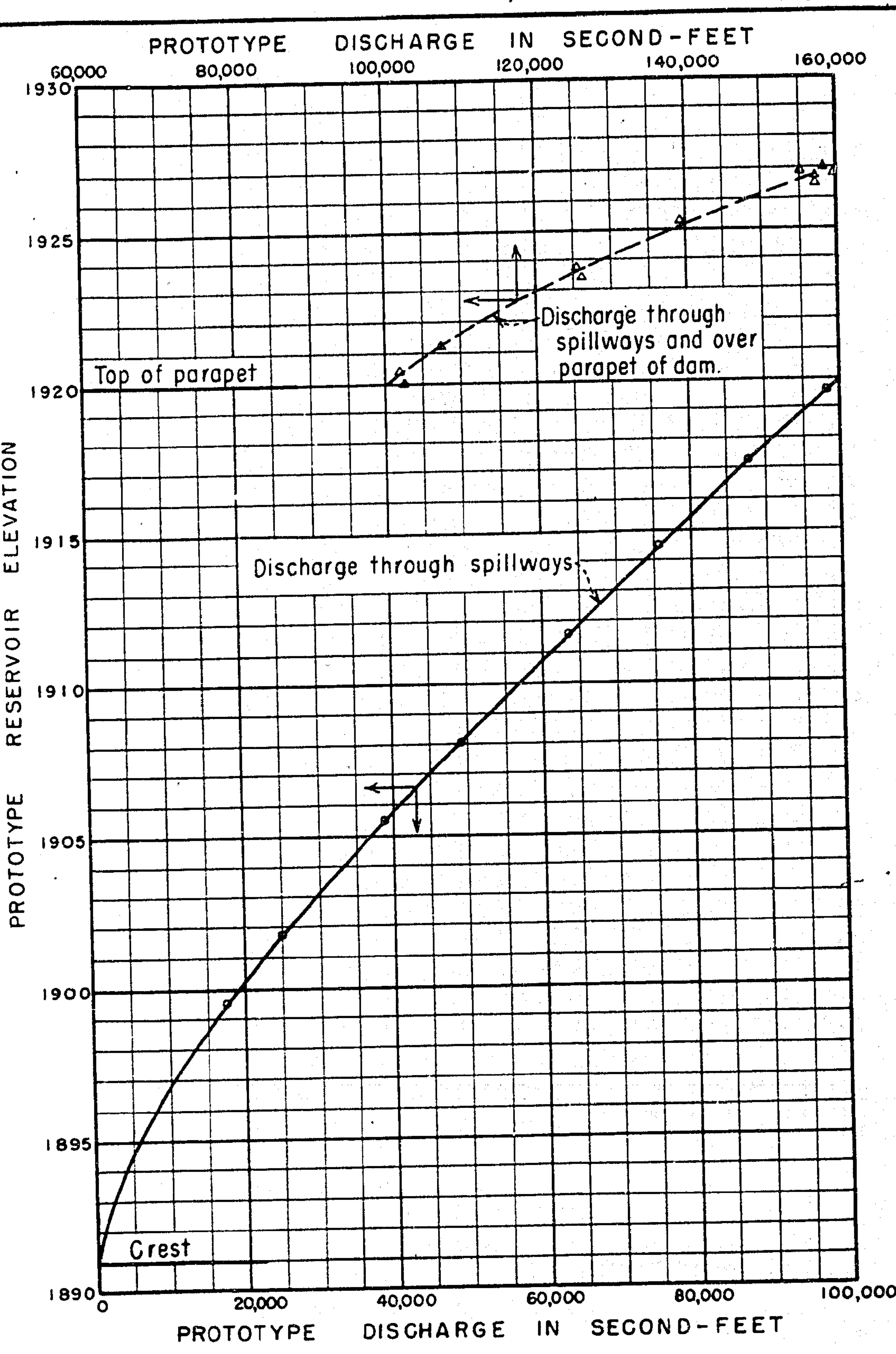
A. Right Spillway

B. Left Spillway

C. Reservoir Elevation 1920.0
Discharge 100,000 Second-feet

D. Reservoir Elevation 1926.46
Discharge 157,000 Second-feet

FLOW CONDITION WITH ORIGINAL SPILLWAY
HORSE MESA DAM
Scale Ratio 1:90

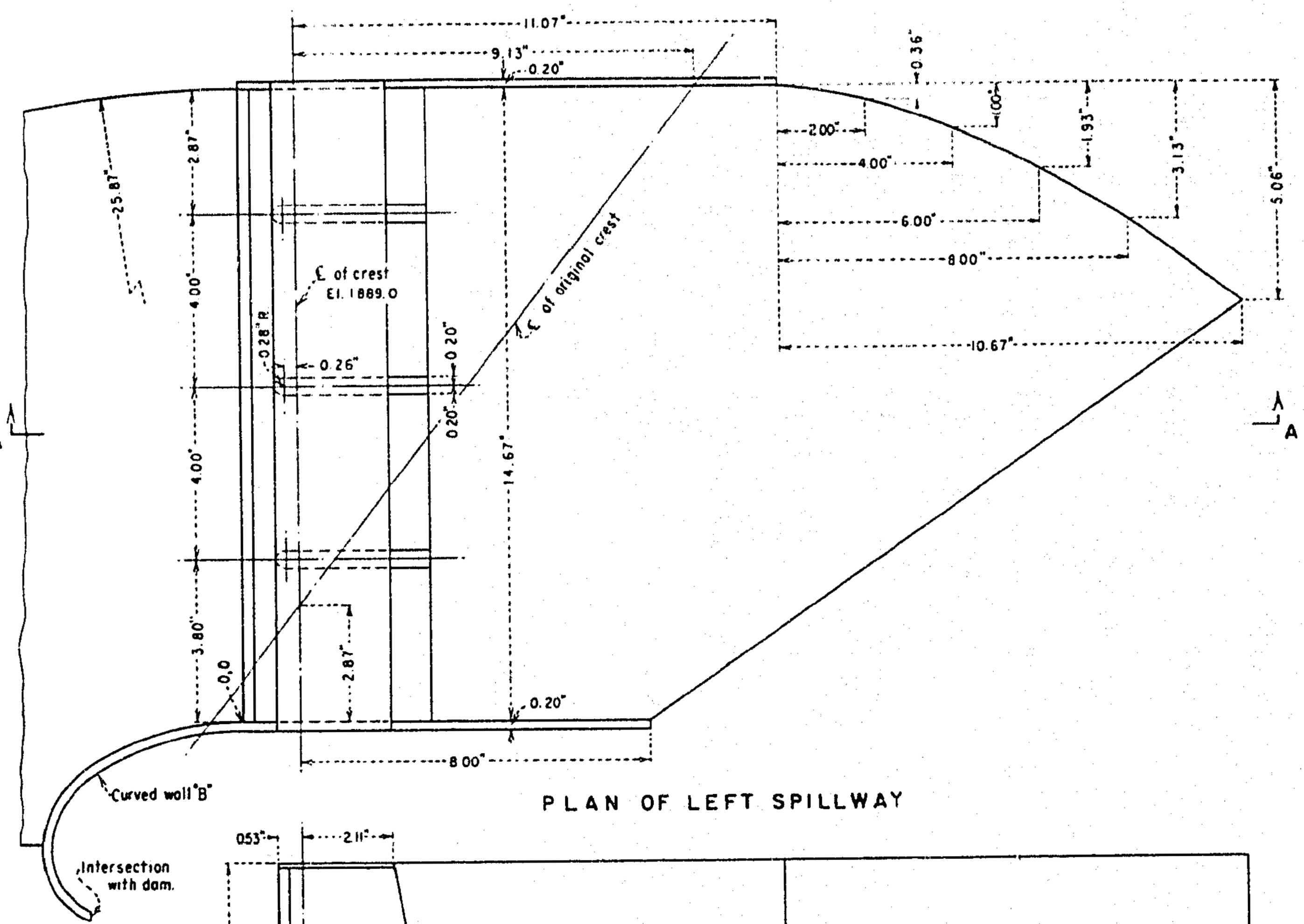


HORSE MESA DAM

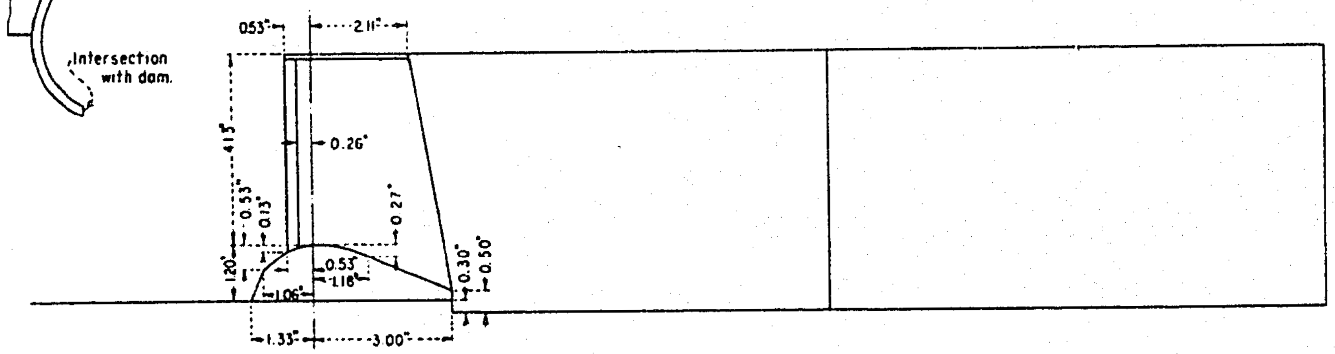
1:90 SCALE MODEL

SPILLWAY DISCHARGE CURVES

ORIGINAL DESIGN



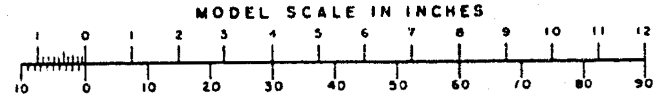
PLAN OF LEFT SPILLWAY



SECTION A-A

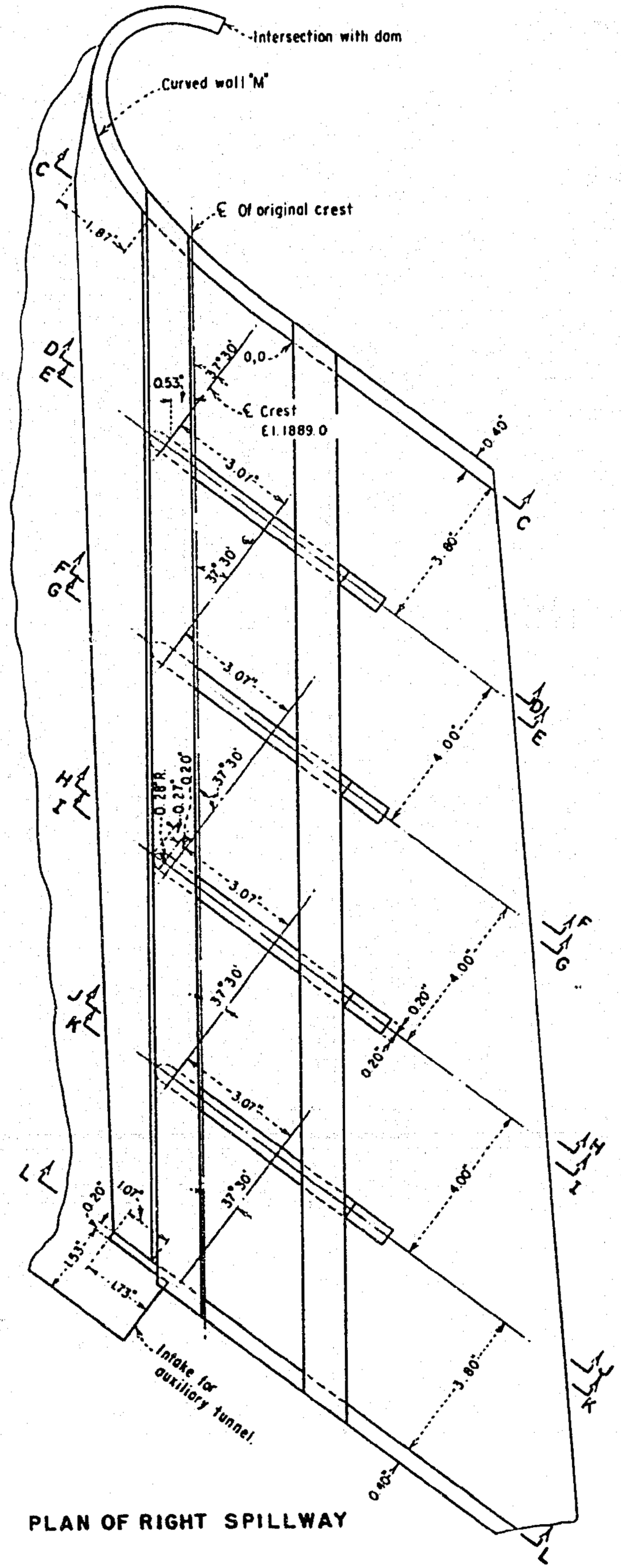
COORDINATES FOR CURVED WALL "B"

X (IN.)	Y (IN.)	
1.30	0.15	
2.00	0.30	
2.70	0.47	
3.00	0.69	
3.35	1.02	4.58
3.70	1.28	4.44
4.00	1.54	4.25
4.20	1.87	3.95
4.45	2.80	

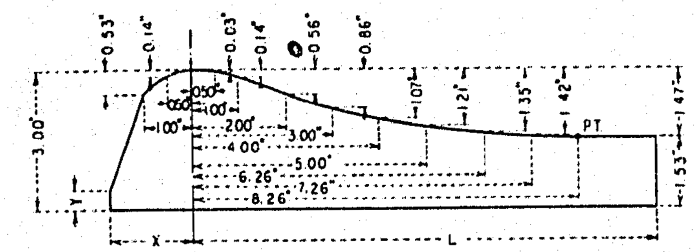


COORDINATES FOR CURVED WALL "M"

X (IN)	Y (IN)	
2.0	0.07	
2.5	0.13	
3.0	0.20	
3.5	0.27	
4.0	0.40	
4.5	0.53	
5.0	0.73	5.20
5.5	1.00	5.07
6.0	1.33	4.80
6.5	1.87	4.40
7.0	3.20	



PLAN OF RIGHT SPILLWAY

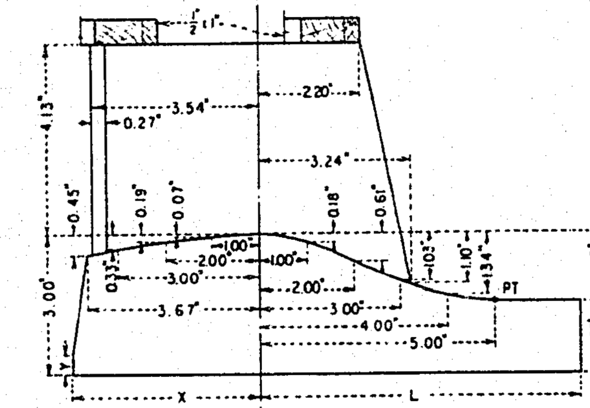


SECTIONS D-D, F-F, H-H, J-J AND L-L

DIMENSIONS FOR ABOVE SECTIONS

SECTION	X (IN)	Y (IN)	L (IN)
D-D	1.76	0.00	10.06
F-F	2.73	0.21	10.53
H-H	2.60	0.72	11.00
J-J	2.33	1.09	11.46
* L-L	2.07	0.87	11.92

*Section L-L has a retaining wall with level top 4.13 inches above crest.



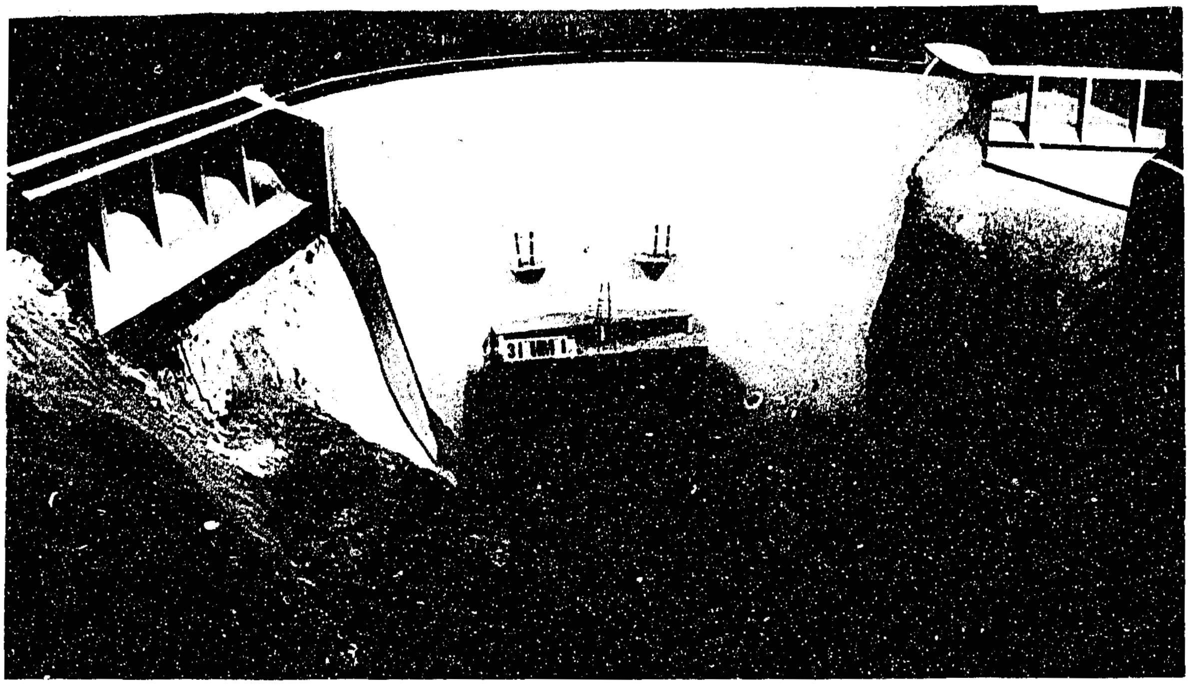
SECTIONS C-C, E-E, G-G, I-I AND K-K

DIMENSIONS FOR ABOVE SECTIONS

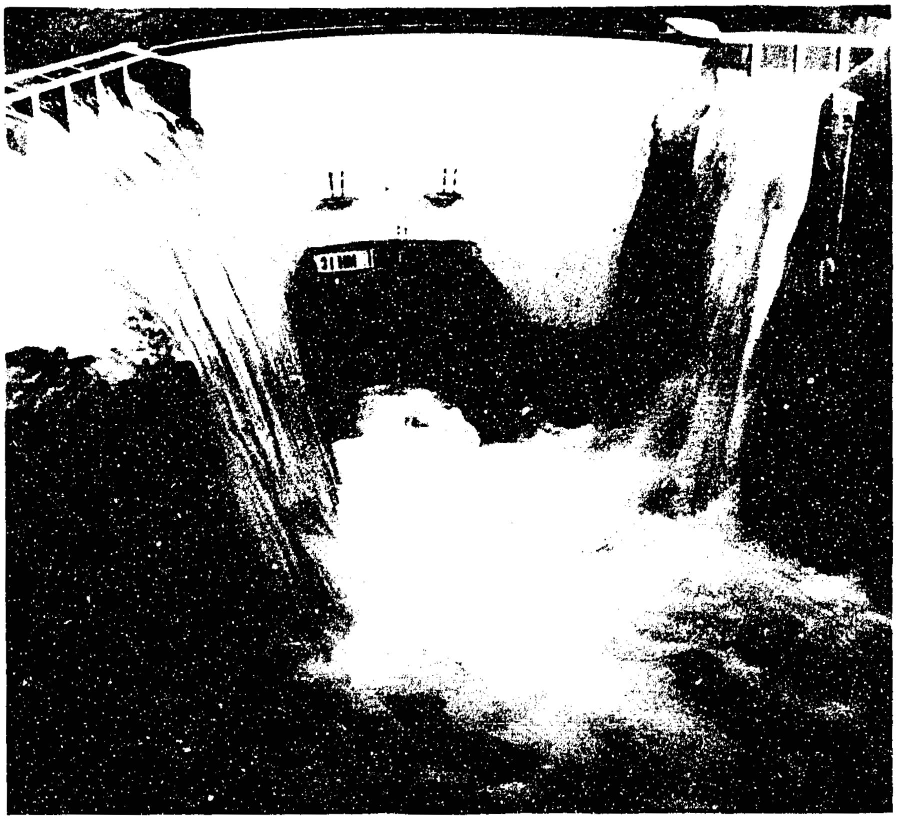
SECTION	X (IN)	Y (IN.)	L (IN.)
* C-C	4.02	0.00	6.87
E-E	4.55	0.00	7.34
G-G	5.34	0.27	7.80
I-I	5.14	0.78	8.27
K-K	4.87	1.07	8.74

*Section C-C has a retaining wall with level top 4.13 inches above crest and no pier.

HORSE MESA DAM
1:90 SCALE MODEL
ECHELON SPILLWAYS - DETAILS



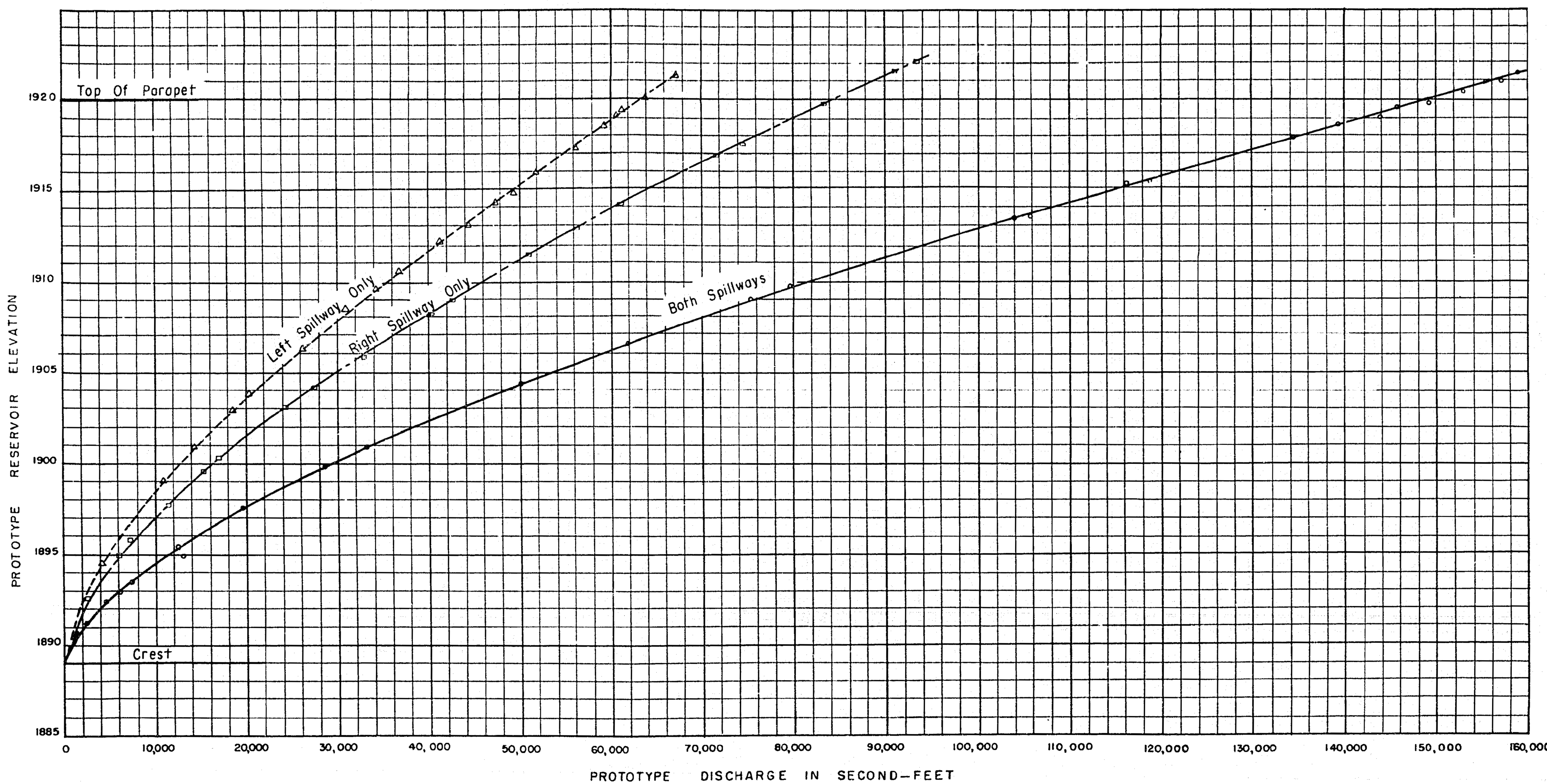
A. No Flow Crest Elevation 1889.0



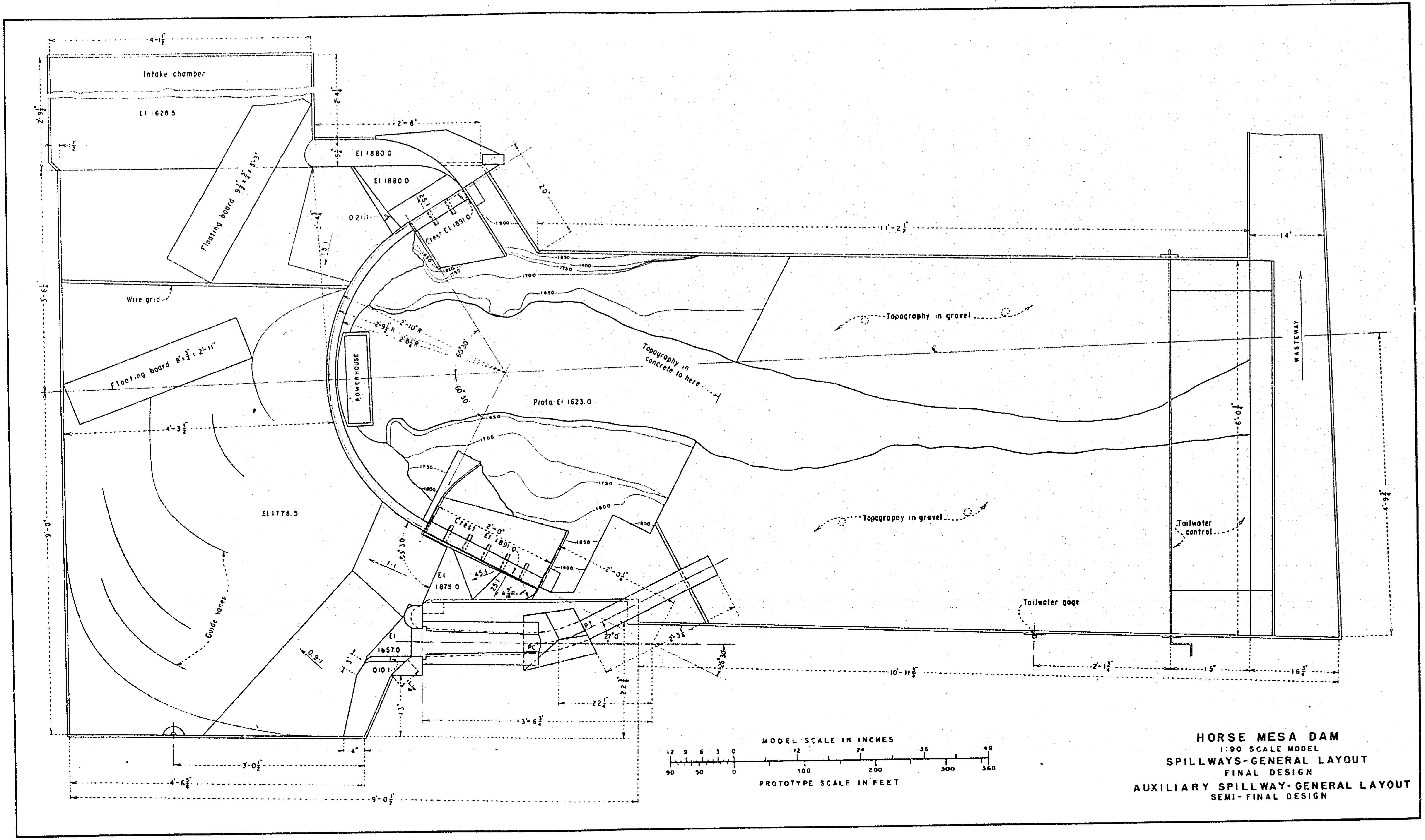
B. Reservoir Elevation 1920.0
Discharge 148,000 Second-feet

FLOW CONDITION WITH ECHELON SPILLWAYS
HORSE MESA DAM
Scale Ratio 1:90

FIGURE 14

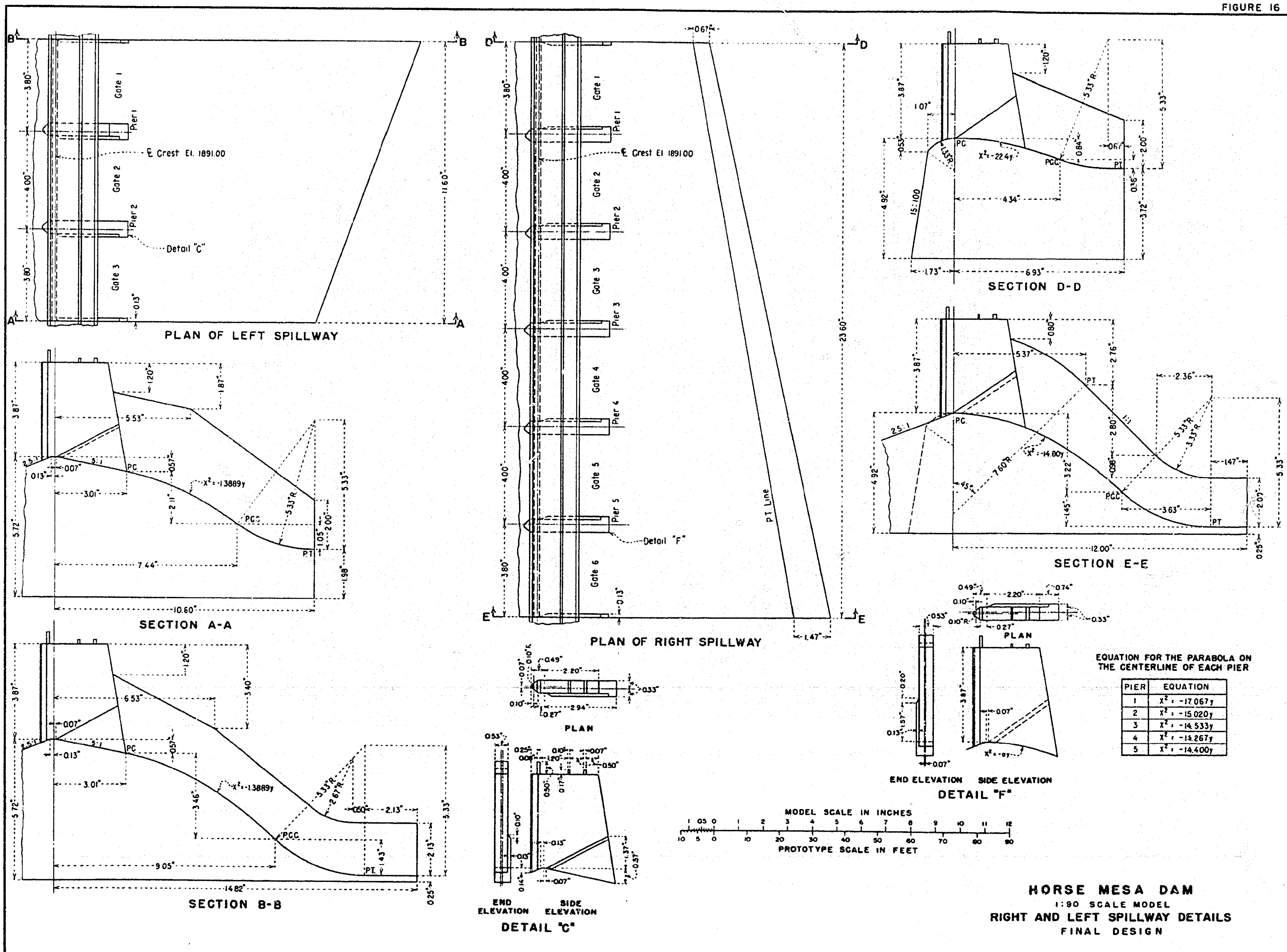


HORSE MESA DAM
1:90 SCALE MODEL
SPILLWAY DISCHARGE CURVES
ECHELON SPILLWAYS



HORSE MESA DAM
1:90 SCALE MODEL
SPILLWAYS-GENERAL LAYOUT
FINAL DESIGN
AUXILIARY SPILLWAY-GENERAL LAYOUT
SEMI-FINAL DESIGN

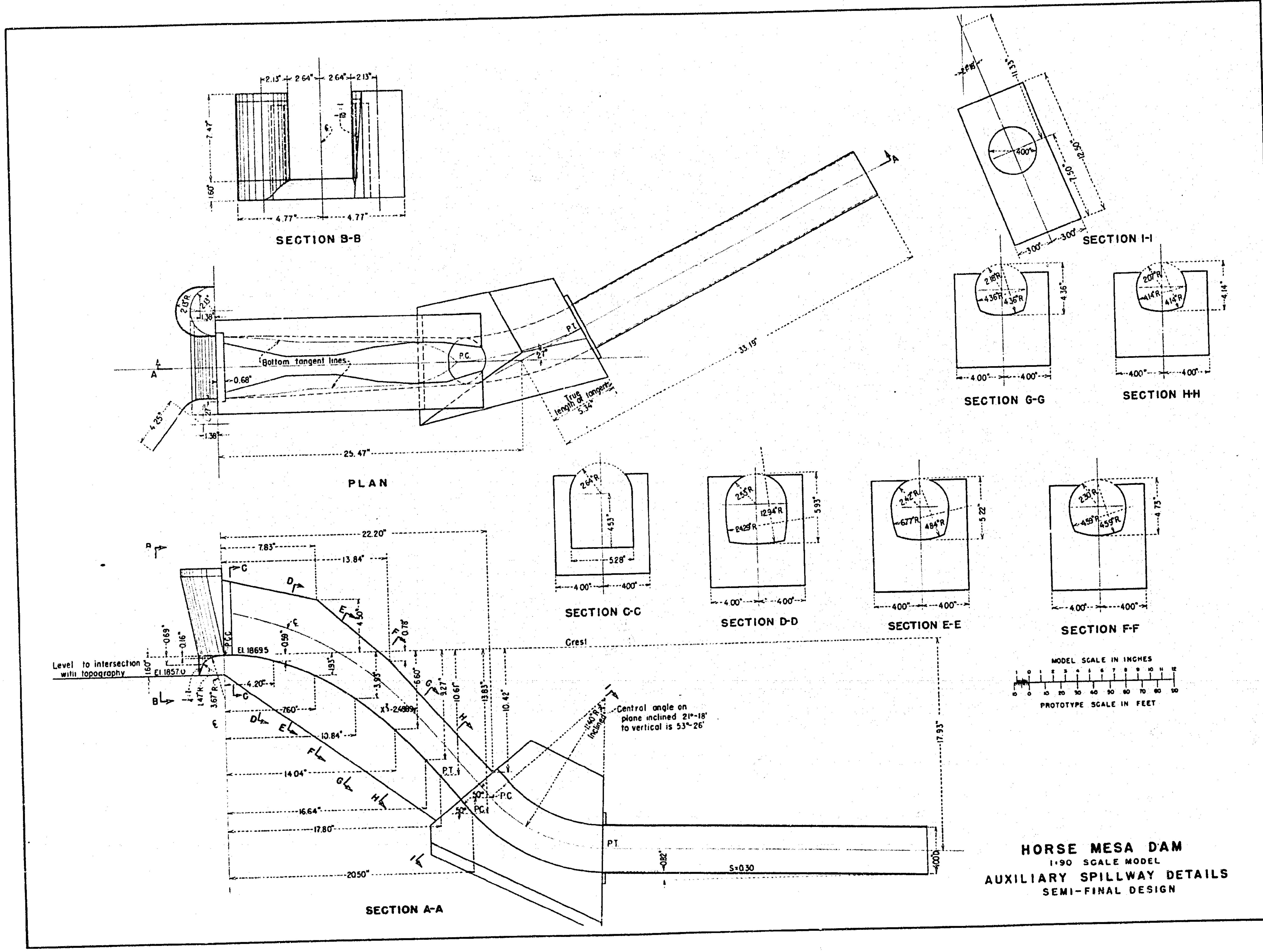
FIGURE 16



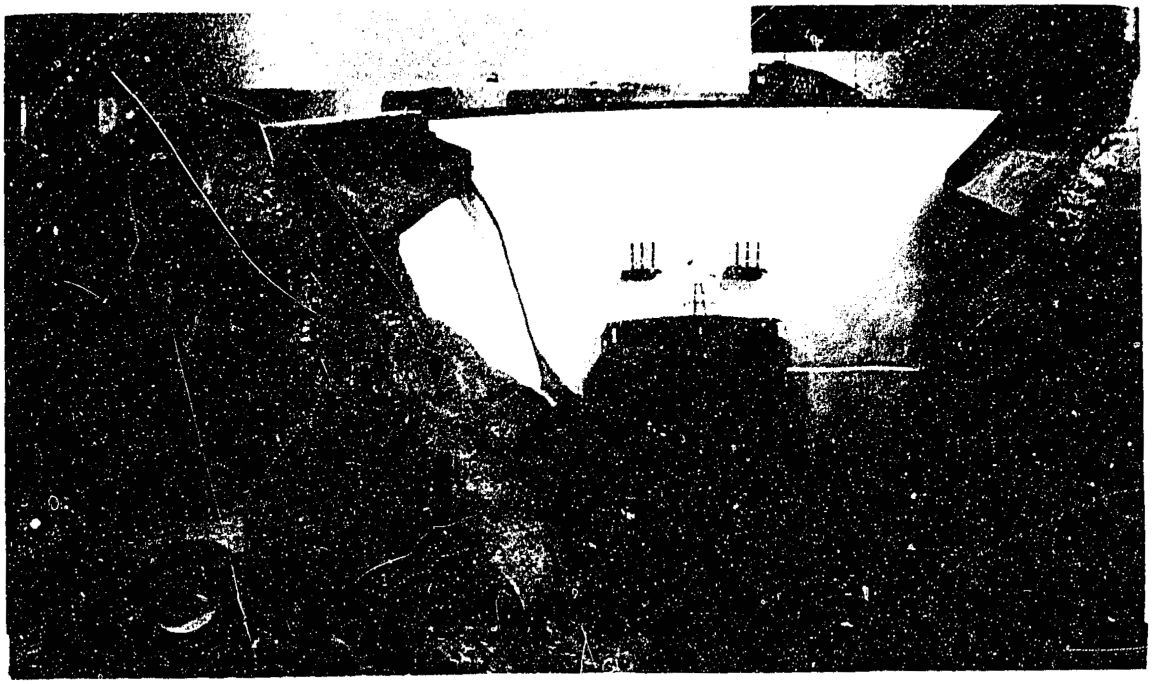
EQUATION FOR THE PARABOLA ON THE CENTERLINE OF EACH PIER

PIER	EQUATION
1	$X^2 = -17.067y$
2	$X^2 = -15.020y$
3	$X^2 = -14.533y$
4	$X^2 = -15.267y$
5	$X^2 = -14.400y$

HORSE MESA DAM
1:90 SCALE MODEL
RIGHT AND LEFT SPILLWAY DETAILS
FINAL DESIGN



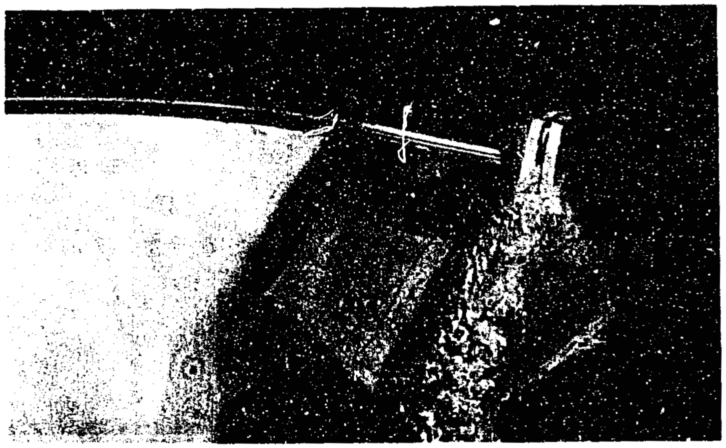
HORSE MESA DAM
1:90 SCALE MODEL
AUXILIARY SPILLWAY DETAILS
SEMI-FINAL DESIGN



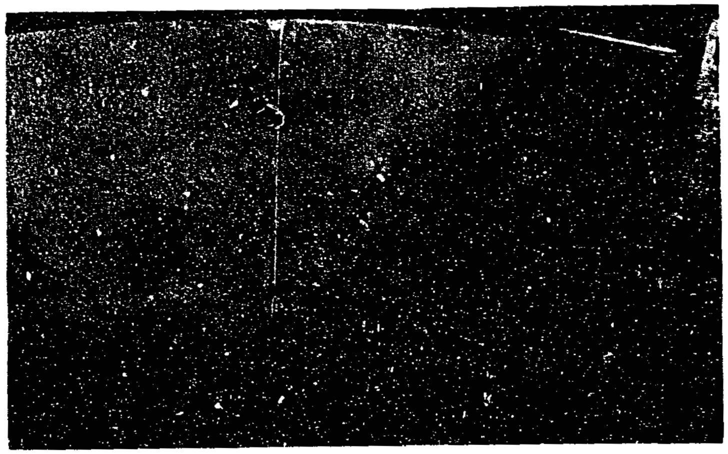
A. No Flow

B. Reservoir Elevation 1920.0
Discharge 150,000 Second-feet

FINAL DESIGN OF SPILLWAYS AND SEMI-FINAL DESIGN OF TUNNEL
HORSE MESA DAM
Scale Ratio 1:90

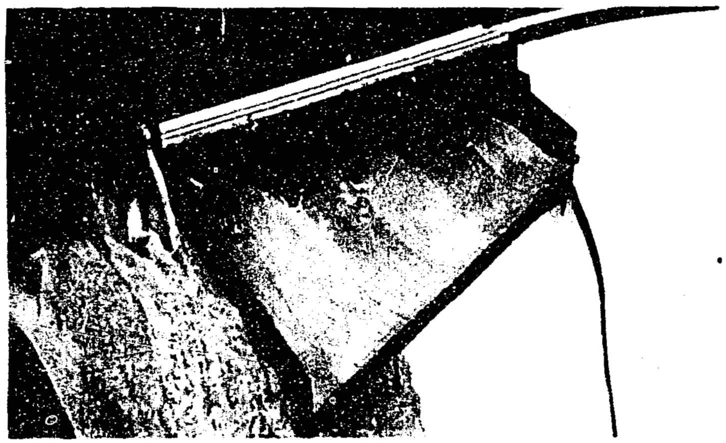


A. No Flow

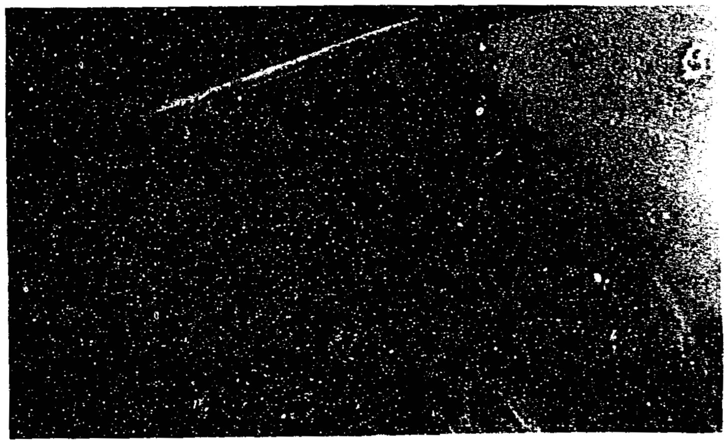


B. Reservoir Elevation 1920.0
Discharge 36,500 Second-feet

LEFT SPILLWAY



C. No Flow



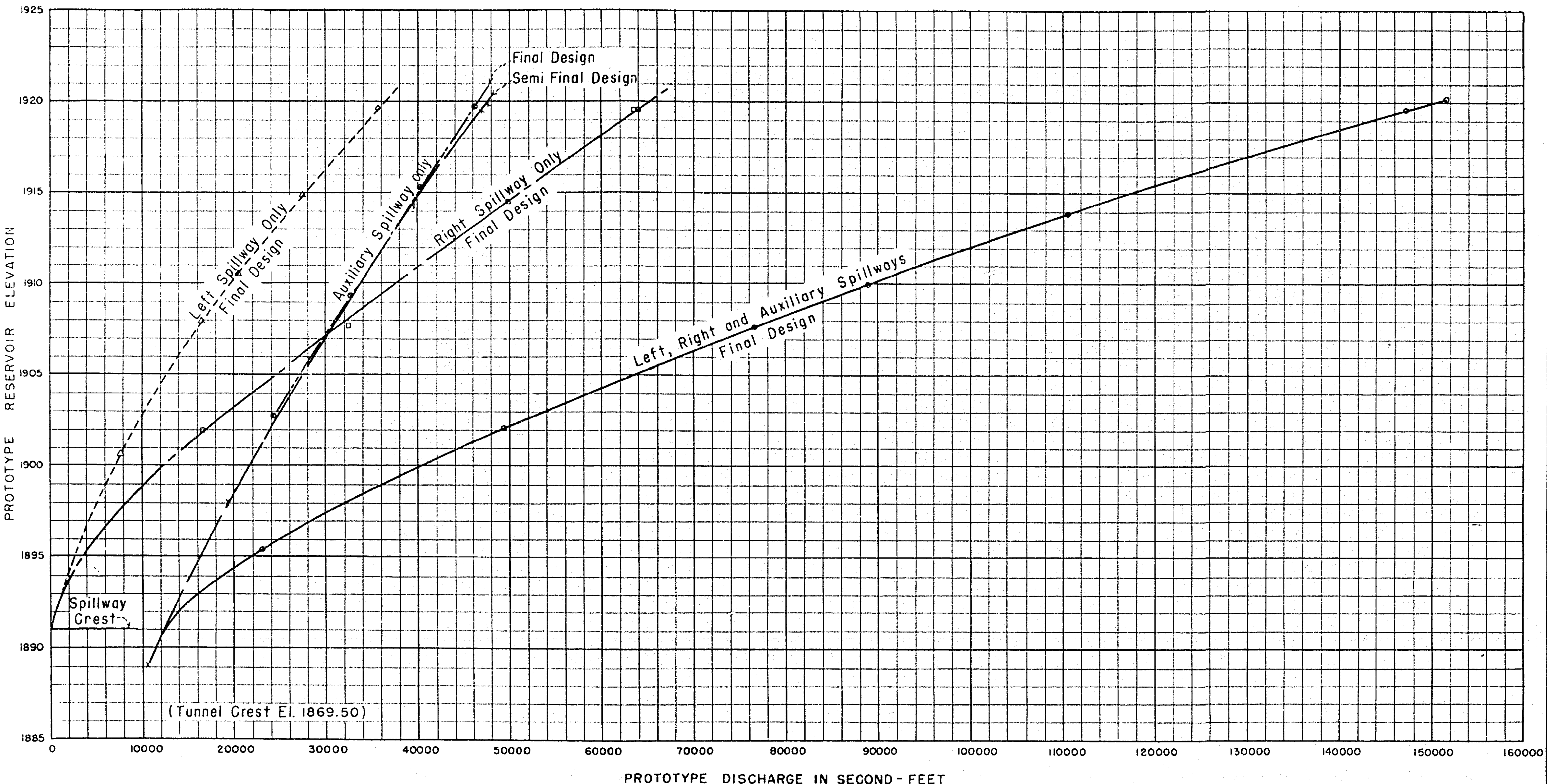
D. Reservoir Elevation 1920.0
Discharge 65,200 Second-feet

RIGHT SPILLWAY

FINAL DESIGN OF SPILLWAYS
HORSE MESA DAM
Scale Ratio 1:90

Figure 19

FIGURE 20

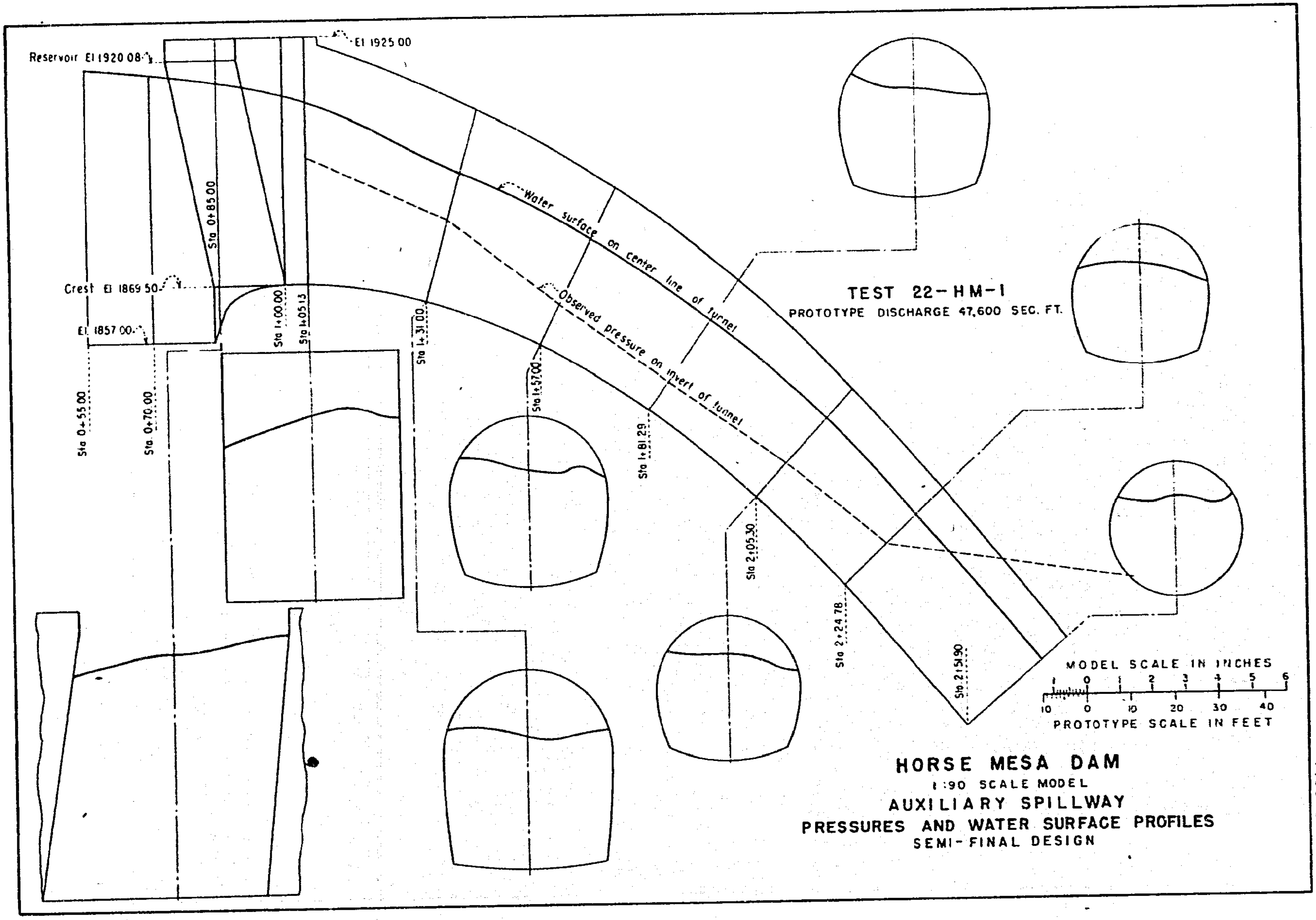


HORSE MESA DAM

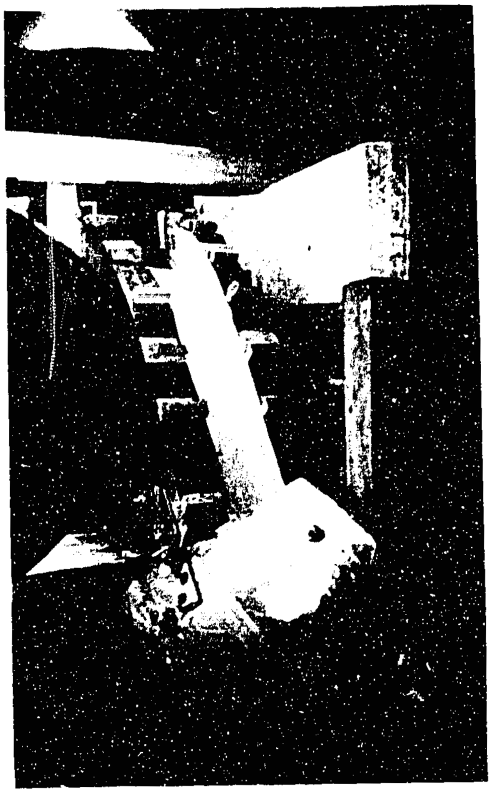
1:90 SCALE MODEL

SPILLWAY DISCHARGE CURVES

SEMI-FINAL AND FINAL DESIGN

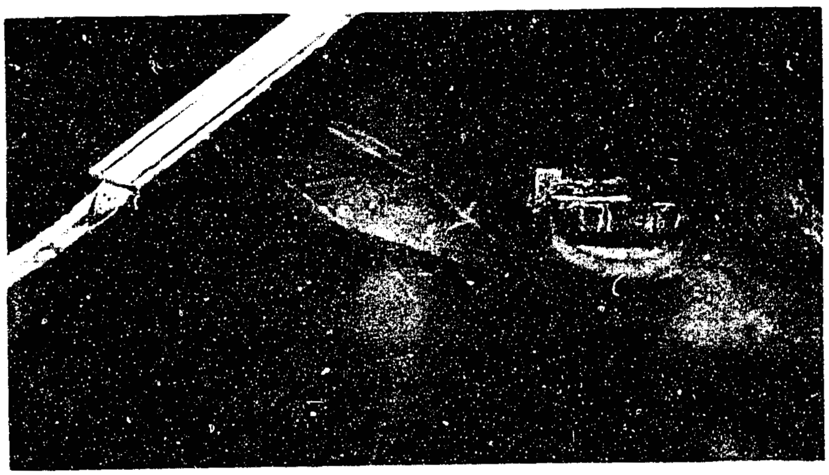


HORSE MESA DAM
1:90 SCALE MODEL
AUXILIARY SPILLWAY
PRESSURES AND WATER SURFACE PROFILES
SEMI-FINAL DESIGN



A. Looking Upstream

B. Close-up

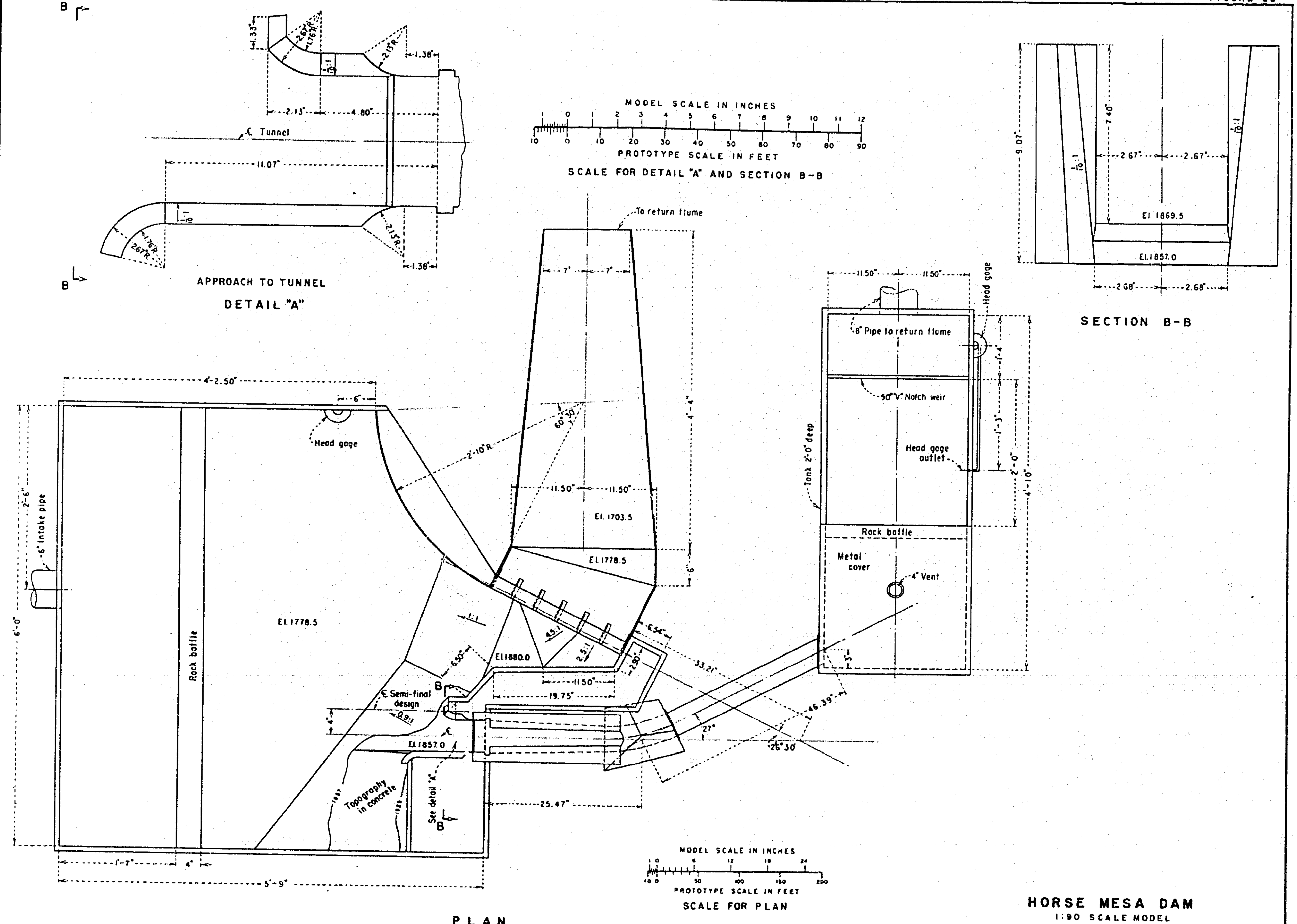


C. Looking Downstream

Reservoir Elevation 1920.0 - Discharge 47,000 Second-feet

SEMI-FINAL DESIGN OF TUNNEL
HORSE MESA DAM
Scale Ratio 1:90

FIGURE 23



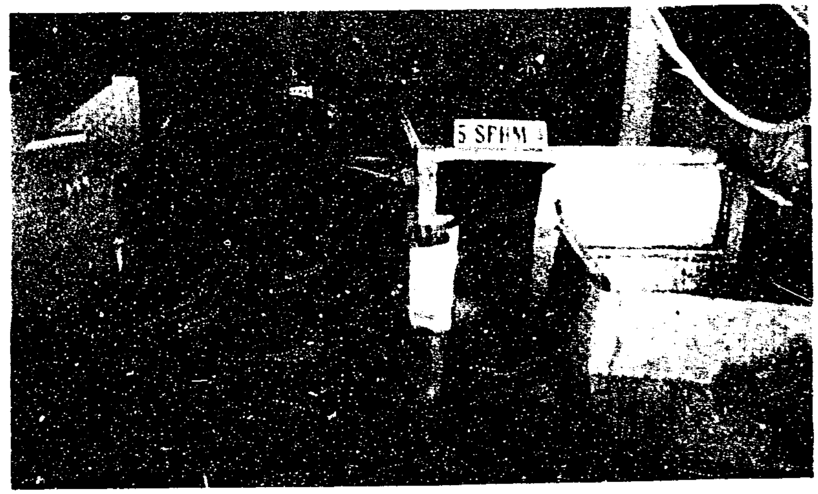
HORSE MESA DAM

1:90 SCALE MODEL

AUXILIARY SPILLWAY

FINAL DESIGN

A. Looking Downstream
No Flow

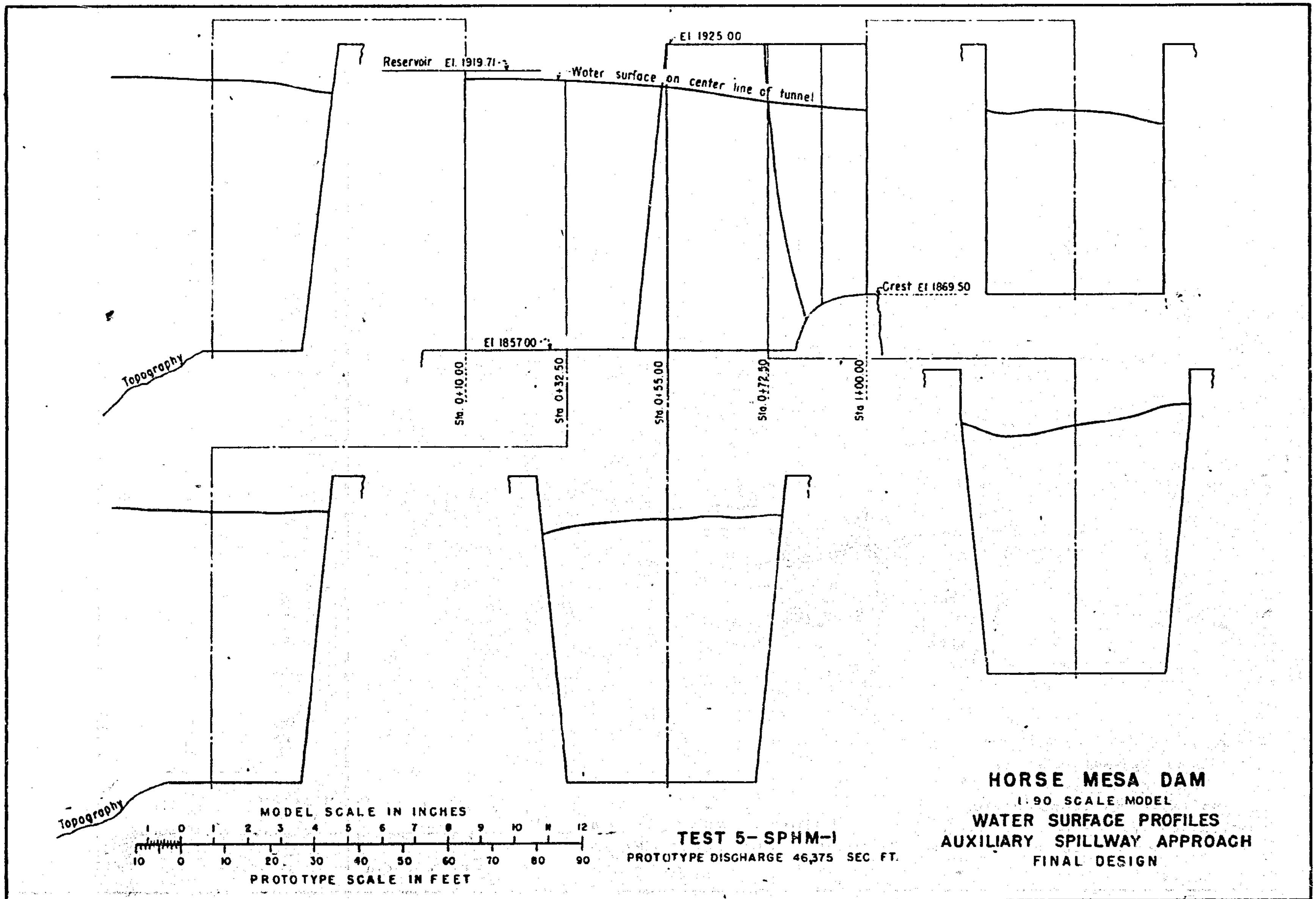


B. Discharge 25,000 Second-feet

C. Discharge 47,000 Second-feet

FINAL DESIGN OF TUNNEL
HORSE MESA DAM
Scale Ratio 1:90

Figure 24



HORSE MESA DAM

1:90 SCALE MODEL

WATER SURFACE PROFILES

AUXILIARY SPILLWAY APPROACH

FINAL DESIGN

FIGURE 25